Inventory and Prototype Monitoring of Natural Resources in Selected National Park System Units 1998-1999

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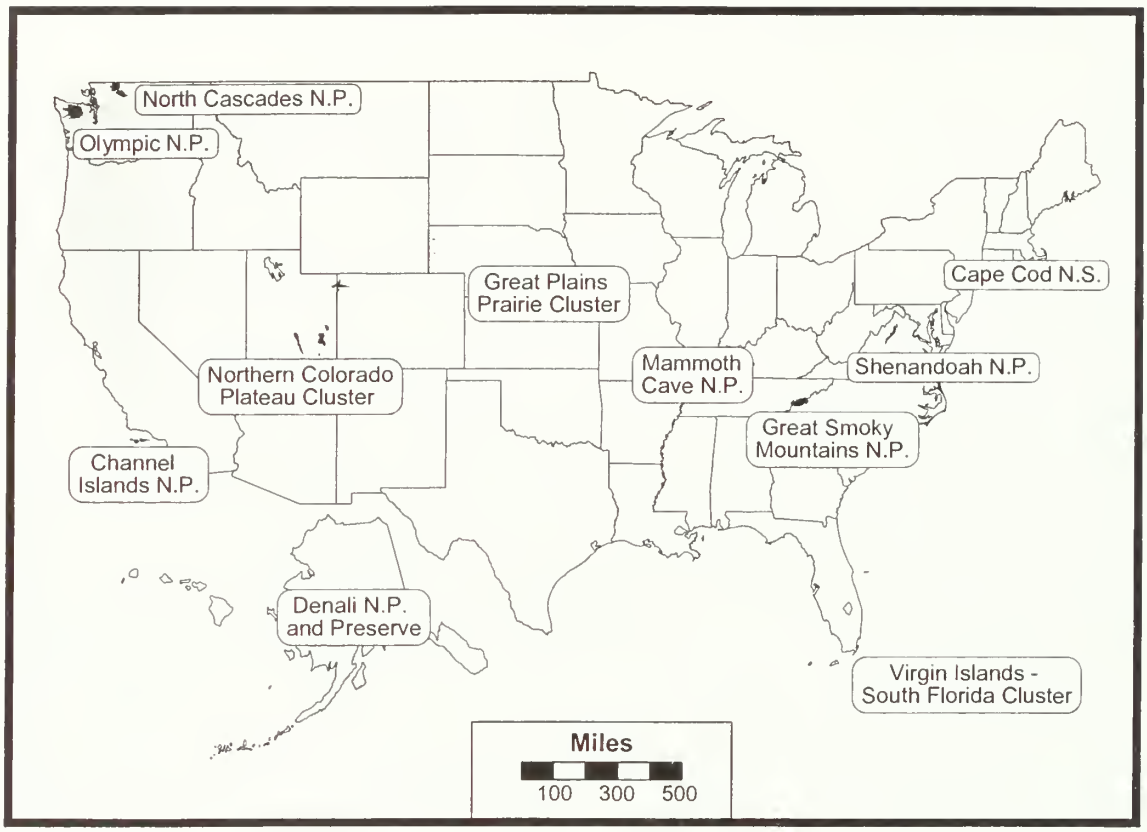
Cover: Long-term monitoring of glaciers in Denali National Park and Preserve, *Photograph by P. Sousanes.* From top to bottom: The island fox, monitoring kelp forest, Photographs from the files of Channel Islands National Park; monitoring fishes in Great Smoky Mountains National Park, *Photograph by* M. Kulp; monitoring salinity in a restored salt marsh on Cape Cod National Seashore, *Photograph by D. Manski.*



NATIONAL PARK SYSTEM UNITS SELECTED FOR
PROTOTYPE LONG-TERM MONITORING OF NATURAL RESOURCES

MAP BY J. GREGSON.

Inventory and Prototype Monitoring of Natural Resources in Selected National Park System Units 1998-1999

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Natural Resource Information Division

The Natural Resource Information Division provides information that advances the management, protection, and understanding of natural resources in the national parklands and in associated ecological communities.

Inventory and Monitoring Program

The five goals of the Inventory and Monitoring Program are (1) the completion of baseline inventories of biological and geophysical natural resources in all National Park System units with natural resources, (2) the development of long-term monitoring of the status and trends of ecosystems at various spatial scales, (3) the application of geographic information systems and other means to identify and evaluate management of natural resources, (4) the integration of inventory and monitoring with park operations, and (5) the coordination of inventory and monitoring with other governmental agencies to further cost-sharing and to avoid duplication of effort.

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A limited number of copies of this report may be obtained from the Manager of the Inventory and Monitoring Program. The report may also be accessed from the World Wide Web at http://www.nature1.nps.gov/pubs.

Contents

Photographs without credit lines are from files of the respective parks.

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The Inventory and Monitoring Program

Overview

The National Park Service is mandated to conserve the natural resources in the National Park System (National Park Service Organic Act, 16 U.S.C. 1 et seq., ch. 408, 39 Stat. 535). Significant natural resources occur in more than 265 of the 378 units of the system, and many are subjected to unfavorable influences from a variety of sources, for example, air and water pollution, urban encroachment, and excessive visitation. Left unchecked, such effects can threaten the very existence of many natural communities in the units. To help prevent the loss or impairment of natural resources, the National Park Service established the *Natural Resource Inventory and Monitoring (I&M) Program.*

The principal functions of the program are the gathering of information about the resources and the development of techniques and strategies for monitoring the ecological communities in the National Park System. The detection of changes and the quantification of trends in the conditions of natural resources are imperative for (1) the identification of links between changes in resource condition and the causes of changes and (2) the elimination or mitigation of such causes. Inventory and monitoring provide important feedback about natural resource conditions to management, trigger specific management, and permit an evaluation of managerial effectiveness. Ultimately, the inventory and monitoring of natural resources will be integrated with park planning, operation and maintenance, visitor protection, and interpretation. The integration will establish the preservation and protection of natural resources as an integral part of park management and improve the stewardship of natural resources by the National Park Service.

The tremendous variability in the ecological conditions, sizes, and management capabilities of national parks poses significant problems for ecological monitoring throughout the National Park Service. To deal with this ecological and managerial diversity, the I&M Program used a competitive process of selecting parks in which *prototype experimental monitoring* of each of ten major biomes could be conducted.

To ensure that the broad range of managerial situations is adequately represented, three of the prototypes were selected as *clusters*, i.e., groupings of 4-6 small units, each of which lacked the full range of staff and resident expertise for long-term monitoring on its own. Monitoring in the selected parks varies widely by structure and function of a park. However, the monitoring of trends in species abundance, population dynamics, watershed ecology, and other indicators of environmental change tends to be uniform throughout the prototypes. Notwithstanding, all monitoring is designed to provide useful ecological information for addressing questions beyond today's issues.

Protocols and expertise developed by the selected parks are shared with other parks in similar ecological and managerial settings. The selected parks also serve as training centers for natural resource managers throughout the National Park Service.

Staffing

In 1999, the core staff of the service-wide I&M Program consisted of its manager, a monitoring specialist, an information management specialist, and three part-time research associates in Fort Collins, Colorado, and a soil scientist in Denver. A National Advisory Committee—which consists of park superintendents, natural resource management specialists, program managers, and research scientists of the Biological Resources Division (US Geological Survey; Appendix)—develops strategic policies and makes programmatic, technical, and budgetary recommendations to the program manager who refers them for approval to the Deputy Associate Director of Natural Resource Stewardship and Science. *Ad hoc* working groups of technical experts from the field convene as necessary to address specific policies and technical issues. Natural-resource personnel in support offices provide coordination between parks and the national program office.

Partnerships

U.S. Geological Survey

Prototype monitoring and basic inventories are being implemented in close partnership between the

National Park Service and the Biological Resources Division of the U. S. Geological Survey. During the initial phases of research and design of long-term prototype monitoring—usually a period of 3-5 years—funding and full-time operational staff are provided by the Biological Resources Division. After completion of research and protocol designs, monitoring is considered operational. From then on, funding and full-time employees become the responsibilities of the National Park Service.

IMPROVE, NADP/NTN, and States

Air pollution is affecting natural resources in parks. To determine background conditions and track changes in air pollution and their effects on the resources, the National Park Service monitors visibility, ambient concentrations of particulate matter, gaseous air pollutants, and wet deposition in many parks. Visibility is monitored as part of the IMPROVE (Interagency Monitoring of Protected Visual Environments) national visibility monitoring network that is jointly funded and operated by the U.S. Environmental Protection Agency, the National Park Service, states, and other land management agencies. Wet deposition (precipitation chemistry) is monitored through the service's participation in NADP/NTN (National Atmospheric Deposition Program/National Trends Network). Gaseous air pollutants are also monitored by networks operated by the National Park Service and states. The networks provide data that are critical for understanding the effects of air pollution on ecosystems in parks.

Budget

The I&M Program is funded by annual line-item appropriations from the U. S. Congress. The Fiscal 1999 I&M Program budget was $5.855 million of which 12% were used for salaries and program administration, 72% for park inventories and data management, and 16% for long-term ecological monitoring.

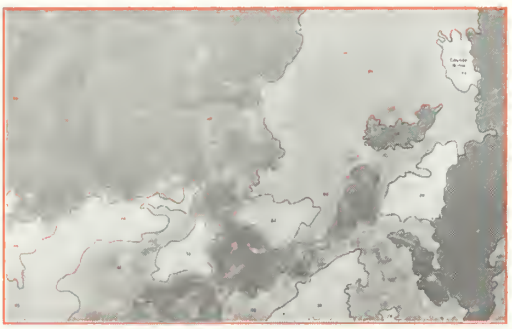
The Selected National Park System Units

Prototype long-term ecological monitoring of natural resources in 1999 continued in 7 of 11 selected parks (Table 1). The 7 parks represent 6 biomes; deciduous forest is represented by 2 parks.

Table 1. The seven National Park System units in which prototype monitoring has been implemented and the biomes that the units represent.

Prototype	Biome
Cape Cod National Seashore, Massachusetts	Atlantic-Gulf Coast
Channel Islands National Park, California	Pacific Northwest Coast
Denali National Park and Preserve, Alaska	Arctic-subarctic
Great Plains Prairie Cluster; Iowa, Minnesota Missouri, and Nebraska	Prairie and grassland
Great Smoky Mountains National Park, Tennessee and North Carolina	Deciduous forest
Shenandoah National Park, Virginia	Deciduous forest
Virgin Islands-Southern Florida Cluster	Tropical and subtropical

Inventories of Natural Resources



Aerial soil map. *Photograph by P. Biggam.*

The I&M Program is committed to conducting inventories in about 260 National Park System units with significant natural resources. Since 1992, the program has funded 560 inventories of various natural resources and verified species lists from 95 units. Progress in inventories of bibliographies, base cartography, vegetation, and soils has been significant. Baseline assessments of water quality and geologic bibliographies in all natural resource parks also were funded. The assessment of baseline water quality was funded jointly with the Water Resources Division of the National Park Service.

Twelve natural resource data elements are the core set of the minimum information for park management, planning, and natural resource protection (Table 2). The I&M Program will complete the basic resource data sets for each National Park System unit with natural resources. For cost effectiveness and quality control, several of the inventories are done by other agencies under national-level contracts and cost-sharing arrangements. Specialized inventories of other resources, for example, invertebrates or fossils, are the responsibility of parks.

Table 2. The 12 natural resource data elements or core set of minimum information for park management, planning, and natural resource protection.

Air-quality-related values
Base cartographic data
Geology map
Location of air quality monitoring stations
Natural resource bibliography
Precipitation and meteorological data
Soils map
Species distribution and status of vertebrates and vascular plants
Species list of vertebrates and vascular plants
Vegetation map
Water-body location and classification
Water-quality data

Channel Islands National Park, California.

Northern Lights in Denali National Park and Preserve.
Photograph by B. Truesdell.

Monitoring and Status of Natural Resources

Golden Eagle in Denali National Park and Preserve.

Overview

National parks have inspired, awed, and brought enjoyment to countless millions throughout this century. In recognition of these national treasures, the U.S. Congress gave the National Park Service the mandate of preserving, protecting, and maintaining the health and integrity of park resources for the enjoyment, education, and inspiration of this and future generations. But management of the national parks is an extremely complicated and difficult task. Park ecosystems are complex and vary tremendously over time and space. Managers must be capable of determining whether the changes they observe in park resources are the result of natural variability or the effects of anthropogenic activities. If the latter, then managers must understand park ecosystem processes and mechanisms well enough to know what actions are needed to restore natural conditions. Such knowledge and insights can be obtained only through comprehensive, long-term research and monitoring. Short-term, parochial investigations will not provide the needed knowledge and understanding. In the words of Ralph Waldo Emerson: *The years teach much which the days will never know.*

Part III of this report consists of descriptions of long-term ecological monitoring and the status of the monitored geophysical and natural resources in two clusters and five National Park System units. Not all of the monitoring programs are at the same stage of implementation, but all hold the promise of enhancing the management and protection of park resources.

Air Quality

Air pollution in National Park System units reduces visibility, injures vegetation, changes lake and stream chemistry, and causes the deterioration of cultural resources. Under the Clean Air Act (Public Law 101-549), the Organic Act, and other legislation, the Department of the Interior must protect resources in the units from these effects.

Since the late 1970s, the National Park Service has monitored visibility and ambient levels of fine particles, ozone, sulfur dioxide, and wet deposition in national parks. Visibility, including photographic, optical, and fine particles, is monitored as part of the Interagency Monitoring of Protected Visual Environments (IMPROVE), which is cooperative national monitoring of visibility by the US Environmental Protection Agency and federal land managing agencies. Wet deposition is monitored as part of the service's participation in the National Atmospheric Deposition Program/National Trends Network(NADP/NTN). The service developed its own network for the monitoring of gaseous pollutants and meteorology, which is supplemented by states in some locations. These networks are essential to the understanding of the effects of air pollutants on ecosystems in parks that previously were presumed to be relatively free of anthropogenic stresses. Before the service's networks were established, monitoring in national parks was scarce because EPA and the states placed priority on health-related monitoring of air quality in urban areas. When the Congress provided additional funding in 1986 and 1987, the National Park Service was able to expand its network and establish a data center to process, validate, and archive data. Ozone, sulfur dioxide, and meteorological data that the service collects are entered into EPA's national database for use by EPA, state agencies, and researchers. Visibility and wet deposition data are available on the Internet (visibility data ftp://alta_vista.cira.colostate.edu; wet deposition.html://nadp.sws.uiuc.edu.)

During 1989-98, ozone levels did not significantly change in Cape Cod National Seashore. The worst visibility improved, ozone levels increased, and sulfate concentrations in precipitation slightly decreased in Denali National Park and Preserve. In Great Smoky Mountains National Park, visibility declined on the visually dirtiest days, ozone levels increased, and sulfate concentrations in precipitation decreased slightly. Ozone concentrations increased and sulfate concentrations in precipitation slightly decreased in Shenandoah National Park.

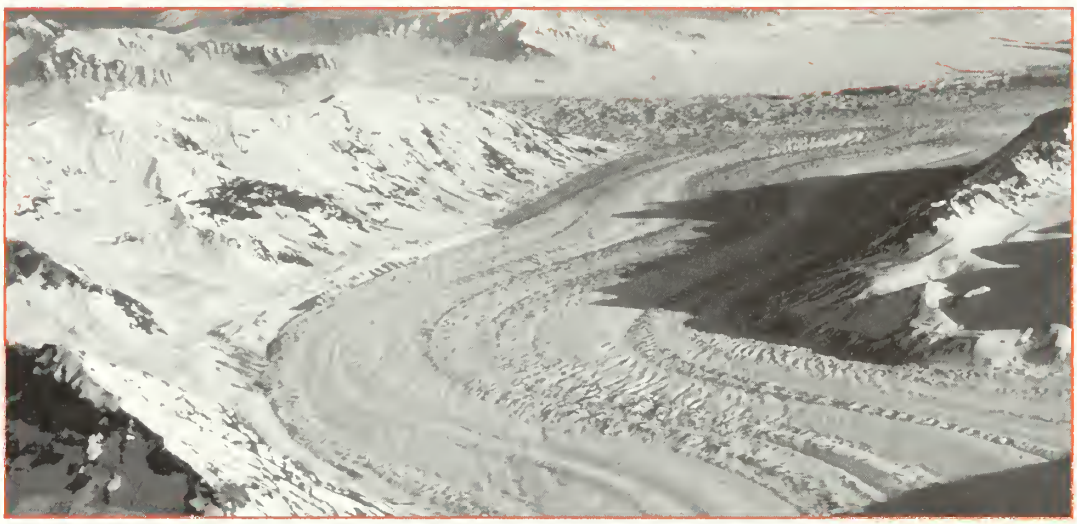
Surficial Processes

The Dynamic Glaciers of Denali National Park and Preserve

Glacial ice covers one sixth or about 405,000 ha of Denali National Park and Preserve, and glacial activity has shaped much of the terrain in the park. The alpine glaciers in the park include some of the largest in North America and many surging glaciers.

The relation between glaciers and climate is perhaps the most relevant and pressing topic in modern research on glaciers. The indications of climatic change or global warming and its effects on the ecology of the national parks may best be detected in a relatively undisturbed ecosystem at higher latitudes in a subpolar climate such as Denali National Park and Preserve. The amount of ice that is gained or lost through time (mass balance) is an indicator of change in the relative health of glaciers and of the magnitude and duration of climate change.

Glacial activity in Denali National Park and Preserve is monitored to determine the regional effects of natural and anthropogenic climate change on the ecology of the park. Data are collected on glacier thickness and longitudinal profile, rate of ice flow, and chemistry and sediment load of melt water. Information from 1999 revealed that extreme melting took place on the lower half of the East Fork Toklat Glacier. Near the glacier's terminus, the ice thinned by approximately 3.6 m, equal to roughly –3.2 m of equivalent water. At higher elevations near the head of the glacier, the mass balance was also negative, although less so. In that region, the glacier thinned by approximately 0.8 m or a water equivalent of -0.7 m. The trends in mass-balance change during the previous 7 years continued in 1999. The Kahiltna Glacier gained approximate 0.4 m of water equivalent mass at the index survey site. This gain of mass



Glacier in Denali National Park and Preserve.

Shoreline Dynamics: Overwash of Coast Guard Beach. Cape Cod National Seashore. Since the 1970s, the shoreline has moved more than 100 m landward along this stretch of shoreline. *Photograph by J. Allen.*

Denali National Park Wildnerness. *Map by M. Maloy.*

was about average for gains in the annual mass balance since 1991 and continued a trend of growth in the upper reaches of the Kahiltna Glacier. The Traleika Glacier has had a consistently negative annual mass balance at the index site since monitoring was begun in 1991 and that trend continued in 1999. The glacier lost approximately 0.2 m of water equivalent mass at the index survey site, indicating that the equilibrium line remained above the index site. In 1998, the results of previous surveys on the Traleika Glacier suggested a building of the next surge of the Muldrow Glacier system of which the Traleika Glacier is a tributary. This was indicated by a thickening and acceleration of the ice in the Traleika Glacier despite the consistently negative trend in mass balance (a behavior that has been observed in other glaciers prior to a surge). A surge seemed no more imminent in 1999 than in 1998. However, the approximate duration between surges of the Muldrow Glacier system is 50 years. The last surge occurred in 1956. Another surge, therefore, may occur at any time between now and approximately 2006 or beyond.

Shoreline Dynamics

Shoreline dynamics are significant processes that affect natural and cultural resources and their management in coastal parks such as Cape Cod National Seashore. Sea level rise—natural or in response to global warming—results in net landward migration of the shoreline and alters the physical aspects of shoreline habitat. Although landward migration of the shoreline is a natural response to storms and sea level rise, it can cause an eventual loss of static biological resources such as coastal bluffs and wetlands, cultural resources such as light-

houses, and infrastructure. The structure of mobile coastal habitats such as barrier islands and spits may change, but the structure is usually not lost. Anthropogenic inlet stabilization, dune rehabilitation, beach nourishment, and recreational uses may directly or indirectly affect shoreline change by interfering with natural processes.

A UTM (Universal Transverse Mercator)-registered and geo-rectified data set that defines the shoreline position at Cape Cod has been developed in a digital format from historical maps, aerial photographs, and GPS surveys. The location of the shoreline is recorded annually, seasonally, and after storms with GPS, and data are analyzed with Arc-Info. Although most of the seashore's coastline has been relatively stable, there has been accretion at Race Point and erosion from storms at Nauset Light, Coast Guard Beach, and South Beach in Chatham. Monitoring of shoreline change will be continued, and data will be used for resource protection.

Water Quality

Water quality affects biota and ecosystem processes in terrestrial environments through which water passes. The greatest threats to good water quality are nutrient enrichment and acidification from atmospheric deposition and polluted runoff from urban, suburban, and agricultural areas that contains nutrients, toxic pesticides, and hydrocarbons. Acid rain, attributed primarily to combustion of fossil fuel, threatens aquatic biota in poorly buffered streams, for example, in some areas of Great Smoky Mountains and Shenandoah national parks.

Water quality in Great Smoky Mountains National Park is monitored in a site at high elevation in the Noland Divide watershed and in 90 sites that represent the entire range of ecosystem conditions in the park. In 1999, streams that drain the Noland Divide watershed experienced continuous chronic and episodic acidification throughout the year (Table 3). The major findings were that (1) watersheds at the same elevation as the Noland Divide watershed are experiencing similar responses to acid deposition such as low pH, high nitrate concentration, and high sulfate concentrations; (2) the susceptibility of aquatic systems to acidification increases with elevation; and (3) geology and the age of forest-stand affect water quality throughout the park.

In Shenandoah National Park, the focus of monitoring water quality has been on collecting baseline data and on direct effects from atmospheric deposition, insect infestation, and forest regeneration on the composition of stream waters. Quantity and chemical composition of precipitation are sampled in 2 sites, the chemical composition of stream water is sampled in 14 sites, and stream water discharge is measured in 5 sites. The distribution of sampling sites provides geographic coverage and representation of geologic and other landscape factors that determine spatial variation in stream water composition in the park. A comparison of samples from the park with samples from 55 streams in adjacent mountainous areas expands this coverage.

Table 3. Average chemical concentrations in two streamlets, two deposition monitoring stations, and soil solution sampled in the Noland Divide watershed. Great Smoky Mountains National Park, 1999.

Sample Name	pH	ANC, Feq/L	Nitrate, Feq/L	Sulfate, Feq/L
SW Streamlet	5.67	9.05	39.35	30.22
NE Streamlet	5.50	2.09	43.81	42.22
Throughfall	4.07	na	117.80	145.30
Open Site	4.60	na	14.32	30.20
Soil Solution	4.38	na	114.70	101.30

Acidic deposition from atmospheric emissions may be the most serious threat to the integrity of the watersheds in the park (Table 4). The susceptibility of surface waters in the park and in the western Virginian mountain region has been well documented. Past and ongoing effects from acidification of streams include a reduc-

Table 4. Sulfate and ANC trends in streams in Virginia and in Shenandoah National Park, 1988-1997. Significance at $p < 0.01$.

	Streams in Virginia (n = 60)		Streams in the park (n = 12)	
	Number of streams	Number of streams with significant trends	Number of streams	Number of streams with significant trends
SO_4^{-2}				
negative	33	8	10	5
positive	27	4	2	0
ANC				
negative	53	18	10	0
positive	7	0	2	0

tion of species diversity in fish and reproductive failure in brook trout *Salvelinus fontinalis* in the least buffered streams. A recent analysis revealed that a reduction in acid deposition by the 1990 Clean Air Act Amendments (Pub. L. 101-549) will probably not protect sensitive streams in the park and western Virginia from further acidification and biological impairment.

A preliminary analysis of trends from data collected in 1999 indicated that, although concentrations of sulfate (the acid anion derived through oxidation of sulfur) declined in many streams, there is little evidence for decreasing acidification. This finding is generally consistent with trends in acid-base chemistry of acid-sensitive surface waters in other regions of the country. Possible explanations for the lack of recovery, despite decreasing concentrations of sulfate, include reduced availability of base cations in watershed soils or in atmospheric deposition. Another possibility, especially in the park, is the effect of forest defoliation by larvae of the gypsy moth, *Lymantria dispar*. Concentrations of nitrate (another acid anion) increased and ANC (acid neutralizing capacity) decreased after severe defoliation of one the watersheds in the park.

In Virgin Islands National Park, water was sampled quarterly in 15 sites around the island of St. John. Temperature, dissolved oxygen, salinity, conductivity, pH, light transmission, and visibility were measured in the field. Turbidity and suspended solids were measured in the laboratory of the park. Ammonia (NH_3), Nitrate (NO_3^-), Nitrite (NO_2^-), and Phosphate (PO_4^{-3}) samples were processed in the Graduate School of Oceanography, University of Rhode Island. Water temperature has been recorded with five thermisters in underwater housing around Virgin Island National Park and Buck Island Reef National Monument since 1989. The thermisters are set to record data every 2 h and are retrieved from the field every 6 months.

According to light transmission, visibility, turbidity, and total suspended solids measurements, clarity improved at the National Park Service dock and in Reef Bay, declined at Yawzi Point, and was stable in most other sites. Total suspended solids were more variable, revealing a decline of clarity during the first quarter of 1999 and improvements in the second quarter of 1999.

On many days during 1998, the water temperature was above the mean monthly maximum temperature (MMMT). On 10 days at Yawzi Point, water temperatures were at or above MMMT. Warmer than normal water temperatures correlate with incidences of bleaching (loss of pigmentation) in coral.

Aquatic Invertebrate Populations as Indicators of Water Quality

Aquatic invertebrate communities are indicators of watershed characteristics because they integrate and reflect features such as surface geology, soil processes, vegetation, and water source. The relation between aquatic macroinvertebrates and water quality has been well established for more than 100 years. Assessment of water quality by macroinvertebrate community structure is easier and less expensive than direct sampling of physical and chemical constituents. Furthermore, aquatic macroinvertebrates live sufficiently long that they integrate the spatial and temporal variability in all water quality parameters. Aquatic macroinvertebrates are monitored in six national parks in the Great Plains to evaluate the current status of prairie streams and to identify trends in water quality.

The aquatic macroinvertebrates are collected with Hester-Dendy samplers in low-gradient streams and with Surber samplers in high-gradient streams. Three sample collections are made in each site during summer. The macroinvertebrates are identified to various taxonomic levels. Water quality is then determined by comparing four metrics of community structure in the current year against the metrics of a baseline year. The Family Biotic Index (FBI) is calculated for all parks. Parks that use Hester-Dendy samplers also use genus richness, genus diversity, and total density as comparative metrics. Parks that use Surber samplers use family richness, family diversity, and the ratio of the abundance of Ephemeroptera, Plecoptera, and Trichoptera (EPT) to the abundance of the Ephemeroptera, Plecoptera, Trichoptera, and chironomid taxa. Changes in two or more metrics are assumed to indicate that a significant change in water quality has occurred in a site since the baseline year.

Information collected in 1999 revealed that water quality had not changed since the baseline year in Wilson's Creek National Battlefield. A significant decline of water quality in one sampling site suggested potential water quality problems in Agate Fossils Bed National Monument.

Water quality significantly declined in Pipestone National Monument. So few individuals were collected that some metrics could not be calculated. For example, some replicates did not contain any of the taxonomic groups identified to the family level, and neither family diversity nor family richness could be calculated. Similarly, neither chironomids nor EPT taxa were represented in some replicates. The lack of EPT taxa reduced the effective sample size of this metric, increased sample variability, and complicated the identification of significant differences. The strikingly low values of family richness and diversity underscored the need for further investigation into the causes of these declines.

Water quality significantly declined also in Homestead National Monument. Only genus richness or the number of macroinvertebrate genera remained unchanged. Genus diversity or the distribution of individuals among taxa was either unchanged or improved. However, the FBI and density data revealed that the taxa had changed to more pollution tolerant forms and that the overall biomass was significantly depressed. Further investigation into the cause of these declines is warranted.

Aquatic Communities

Kettle Ponds

Twenty kettle ponds occur in the pine-oak forests of Cape Cod National Seashore. Their condition ranges from oligotrophic to eutrophic, and they support a diversity of plant and animal communities including several threatened and endangered species. A growing proportion of the 5 million annual visitors to the seashore are now visiting the ponds. Because of the scarcity of nutrients and base cations in local soils (granitic glacial outwash), most ponds are naturally clear (low phytoplankton biomass) and acidic with low pH-buffering capacity. These conditions make the ponds sensitive to anthropogenic loading of either nutrients (phosphorus and nitrogen) or mineral acids from, for example, acid deposition. During the past few centuries of European settlement and particularly during the past 100 years of industrialization, local and regional land uses have drastically increased the delivery of nutrients, acidity, and metals to the ponds. Management therefore focuses

on control of (1) human activities and land uses that can increase nutrient loading, for example, residential wastewater disposal and shoreline soil erosion; and (2) anthropogenic atmospheric inputs of acid anions and metals.

Besides nutrient loading, local cultural influences on water quality have included deforestation that was followed by forest re-growth in the eighteenth and nineteenth centuries, hydrologic changes, stocking with fish—often with exotic species—in the twentieth century, and liming to enhance the survival of exotic fish by neutralizing the ponds' naturally acidic waters. Deforestation increased lake production and pH, probably, because of increased runoff of nutrients and base cations from shoreline soils. Decreased pond production and pH have been a result of forest re-growth. Hydrologic alterations such as the digging of channels to connect otherwise landlocked ponds to the sea increased access to anadromous fishes and combined with the introduction of exotic species altered the trophic structure of ponds. The altered trophic structure probably changed the species and size distributions and the biomass of the plankton community. Additions of agricultural limestone to the acidic ponds, which are not always well documented, have caused major changes in plankton, invertebrates, and fish.

A limnological characterization of all 20 named kettle ponds on the seashore was first attempted in 1975 and 1976, although specific ponds have been of interest to researchers since at least the 1950s. Seashore staff began occasional sampling in about 1982 and continued through 1991. During 1984-94, the ponds on Cape Cod were included in a quarterly state-wide survey of pH, alkalinity, and major ions, and seashore staff continued collection of such data. In 1992, the National Park Service convened experts in hydrology, limnology, and aquatic ecology to develop clear objectives and a standard set of field and laboratory procedures for annual monitoring of the ponds. The ponds on the seashore have been monitored since, but the protocol was revised twice after reviews by an expanded group of experts.

Kettle pond transparencies seem to have declined concurrent with increased human use during the past 20 years. The pH of heavily used ponds has also increased since 1985 and suggests increased water-column production. In contrast, a large decline of pH in one pond coincided with an episode of sulfate loading from an as yet unidentified source and was followed by increased productivity and decreased clarity.

Staff of Cape Cod National Seashore are presently compiling historic and current limnological data in a data atlas to synthesize paleo-ecological and modern hydrogeological and limnological descriptions, to discern trends in productivity and acid balance, and to provide scientific and popular access to the large body of information on the outer Cape's kettle ponds. Twenty-year trends in trophic state and acid balance are being analyzed and the results will be in the atlas.

Salt Marsh Restoration

About 708 ha (1749 A) of 1827 ha (4511 A) tidal wetlands on Cape Cod National Seashore have been degraded by diking in the nineteenth and twentieth centuries. Since 1930, a dike that bisected an original 200-ha (494 A) salt marsh in Hatches Harbor, Provincetown (Fig. 1), reduced flooding heights and salinity, restricted fish access, and allowed the replacement of salt marsh cord grass *Spartina alterniflora* and salt hay *S. patens* by common reed *Phragmites australis* and other salt-intolerant plants. To rectify this, the seashore has been planning and implementing salt marsh restoration by restoring tidal flow. In 1999, after 12 years of planning and interagency negotiation and 3 years of pre-treatment monitoring, restoration of 24-32 ha (60-90 A) of salt marsh habitat was implemented.

To restore the salt marsh, one 0.61-m (2-ft) diameter culvert were replaced by four 0.9-x-24-m (3-x-7-ft) culverts that are gradually being opened. Two of the four new culverts were opened 10 cm (3.9 In) in May 1999, and tide heights, surface-water quality, porewater quality, halophyte production, and habitat use by birds, fishes, shellfishes, and nuisance mosquitoes are now monitored annually. The monitoring variables were selected on hypothesized changes from restored tidal flow such as increased tidal range, increased dewatering and salinity, decreased sulfides

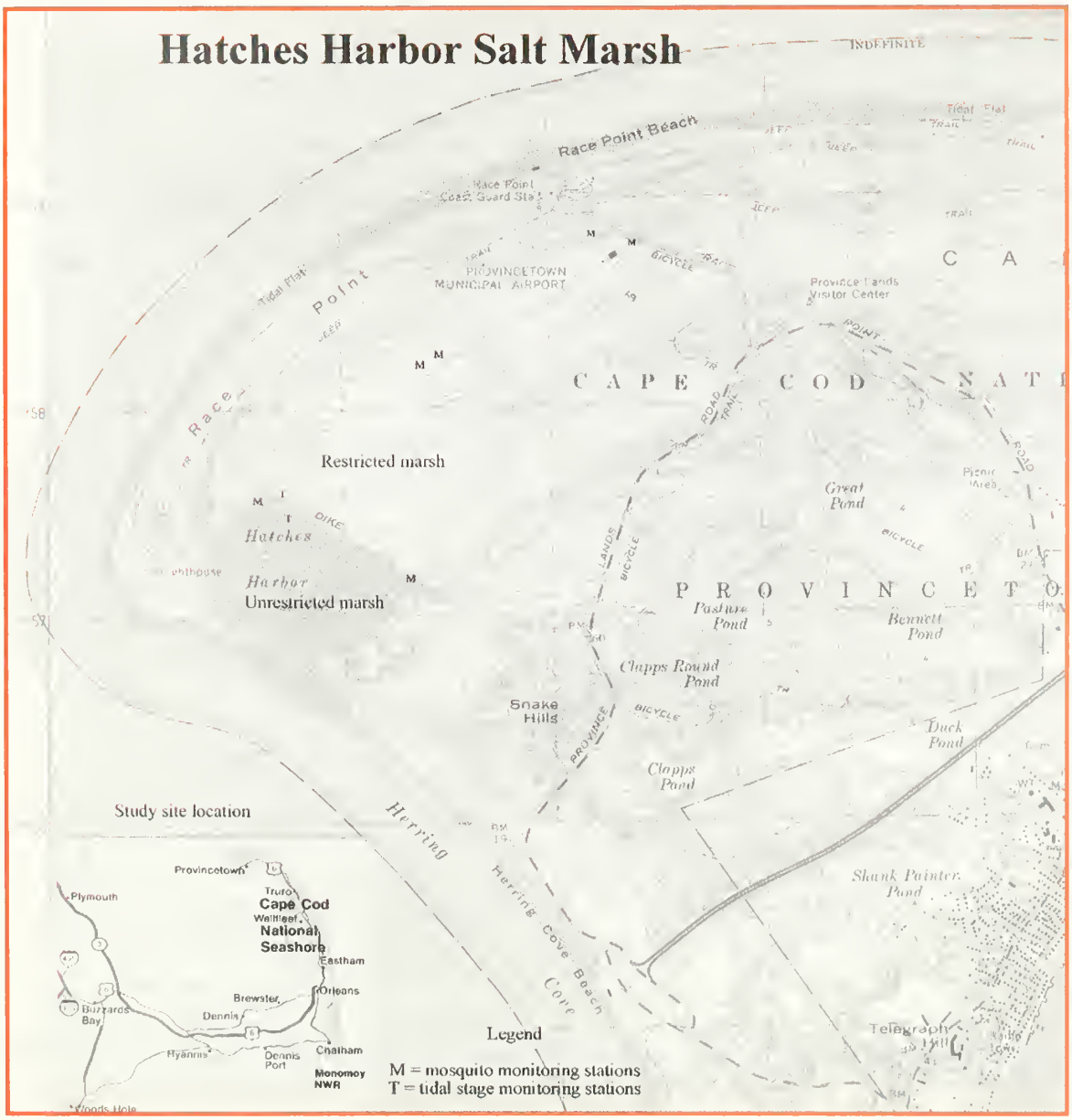


Figure 1. Salt marsh under restoration in Hatches Harbor, Cape Cod National Seashore. Shown are the stations for monitoring the tide stage, transects for sampling vegetation and porewater, and the stations for trapping mosquitoes.

of marsh peat, and reduction of nuisance mosquito populations.

With increased culvert openings, spring tidal range increased by more than 20%. The new culvert cross-sectional area also allows greater drainage of the marsh during ebb tide, which substantially alters the hydroperiod. As a result, seawater is penetrating about 20 m farther into the marsh, which favors re-establishment of salt marsh grasses, fish access to the wetland surface, and probably access by fish to mosquito larvae in floodwater.

The average low tide is lower and reduces low-tide porewater levels even during spring tides. This increases root-zone aeration and improves conditions for the growth of salt-marsh plants. Sulfide, a product of anaerobic decomposition in waterlogged peat, remains low in wetland root zones. In addition, lower low tides enhance drainage and reduce ponding along the airport approach. Lower low tides reduce breeding of floodwater mosquitoes. Neither the absolute nor the relative abundance of salt-marsh mosquitoes increased since restoration began.

Kelp Forest

Kelp forests in Channel Island National Park are monitored to collect baseline information for a better understanding of the natural variation of this resource. The information will be used for sustainable management and protection of the forests.

More than 1000 species inhabit kelp forests in the park. They are organized in assemblages that represent a boreal Oregonian biogeographical province, a temperate Californian province, and a transition zone intermediate between these provinces. Sixty-three taxa were selected to represent kelp forests in the park: 13 algae, 12 fishes, and 38 invertebrates (Table 5). To sample the range of biogeographical and environmental conditions in which kelp forests occur in the park, 16 fixed stations were established. Each station is marked by a 100-m-long transect permanently affixed to the seabed with 11 stainless steel eyebolts and connected with 12-mm-diameter lead-filled woven nylon line. Information about population dynamics of organisms in the kelp forest at these stations is gathered annually from June through October with 9 different sampling techniques. At each station, densities and distributions of discrete benthic organisms are sampled in randomly placed 1-x-2-m quadrants and along 3-x-20-m band transects, percent cover of colonial invertebrates and algae is sampled in 600 randomly selected points, fish abundance is sampled along fixed 2-x-3-x-50-m transects and by roving diver fish counts, videotapes are made of stations to document their appearance, size measurements are collected to determine age structure and population recruitment, temperature data are collected with remote temperature loggers, and species list surveys are conducted.

In 1999, the kelp forest was sampled in 16 sites by 33 National Park Service and volunteer divers in 794 dives and 626 hours of bottom time. Giant kelp *Macrocystis pyrifera* forests were present at five sites, and 11 sites were dominated by echinoderms. Of these 11 sites dominated by echinoderms, four were dominated by purple sea urchins *Strongylocentrotus purpuratus*, two by red sea urchins *S. franciscanus*, three by both purple and red sea urchins, one by both aggregated red sea cucumbers *Pachythyone rubra* and purple sea urchins, and one by both purple sea urchins and the brittle star *Ophiothrix spiculata*.

In 1999, the densities increased of red sea urchins, white sea urchins *Lytechinus anamesus*, and purple sea urchin, bat stars *Asterina miniata*, giant-spined stars *Pisaster giganteus*, and sunflower stars *Pycnopodia helianthoides* (Fig. 2). The increase in the density of the sea stars is an indication of their recovery from the severe decline of their abundance during the 1997-98 El Nino.

In October 1999, biologists of the park, the National Marine Fisheries Service, the California Department of Fish and Game, the U.S. Geological Survey, the University of California-Santa Barbara, the Scripps Institute of Oceanography, and the Delta Oceanographics conducted a 16-day cruise aboard the R/V VELERO IV to evaluate white abalone *Haliotis sorenseni* populations at the southern Channel Islands and offshore banks. Previous surveys of white abalone in the northern Channel Islands at

Table 5. Regularly monitored species in kelp forests by taxonomic grouping, common name, scientific name, and monitoring technique. Channel Islands National Park, 1999.

Taxa/Common name	Scientific name	Monitoring technique
	Algae	
Miscellaneous green algae		R
Miscellaneous red algae		R
Articulated coralline algae		R
Encrusting coralline algae		R
Agar weed	*Gelidium spp.*	R
Sea tongue	*Gigartina spp.*	R
Miscellaneous brown algae		R
Acid weed	*Desmarestia spp.*	R
Oar weed	*Laminaria farlowii*	R,Q
Bladder chain kelp	*Cystoseira spp.*	R
Giant kelp	*Macrocystis pyrifera*	R,Q,M
California sea palm	*Pterygophora californica*	R,Q
Southern sea palm	*Eisenia arborea*	R,Q
Miscellaneous plants		R
	Invertebrates	
Miscellaneous sponges		R
Orange puffball sponge	*Tethya aurantia*	B,S
Southern staghorn bryozoan	*Diaperoecia californica*	R
Miscellaneous bryozoans		R
California hydrocoral	*Stylaster (Allopora) californica*	B,S
White-spotted rose anemone	*Tealia lofotensis*	B
Red gorgonian	*Lophogorgia chilensis*	B,S
Brown gorgonia	*Muricea fruticosa*	B,S
California golden gorgonian	*M.californica*	B,S
Strawberry anemone	*Corynactis californica*	R
Orange cup coral	*Balanophyllia elegans*	R
Cup coral	*Astangia lajollaensis*	R

Table 5 continued

Taxa/Common name	Scientific name	Monitoring technique
	Invertebrates cont'd	
Hydroids	*Diopatra ornata*	R
Ornate tube worm	*Phragmatopoma californica*	R
Colonial sand-tube worm	*Serpulobis squamigerus*	R
Scaled-tube worm		R
	Cypraea spadicea	
Chestnut cowrie	*Lithopoma (Astraea) undosum*	Q
Wavy turban snail	*L. (Astraea) givverosum*	Q,S
Red turban snail	*Asterina (Patiria) miniata*	Q,S
Bat star		Q,S
	Pisaster giganteus	
Giant-spined sea star	*Pycnopodia helianthoides*	Q,S,M
Sunflower star	*Lytechinus anamesus*	B,S
White sea urchin	*Strongylocentrotus franciscanus*	B,S
Red sea urchin		Q,S
	S. purpuratus	
Purple sea urchin	*Parastichopus parvimensis*	Q,S
Warty sea cucumber	*Pachythyone rubra*	Q
Aggregated red sea cucumber	*Haliotis rufescens*	R
Red abalone		B,S
Pink abalone	*H. corugata*	B,S
Green abalone	*H. fulgens*	B,S
Kellet's whelk	*Kelletia kelletii*	B,S
Giant keyhole limpet	*Megathura crenulata*	B,S
California brown sea hare	*Aplysia californica*	B
Rock scllop	*Crassedoma (Hinnites) giganteum*	B,S
California spiny lobster	*Panulirus interruptus*	B
Tunicates		R
Stalked tunicate	*Styela montereyensis*	Q
Miscellaneous invertebrates		R

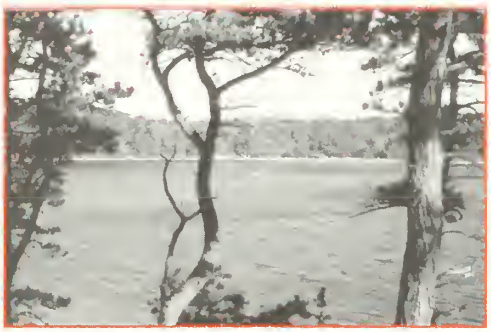
Table 5 continued

Taxa/Common name	Scientific name	Monitoring technique
	Fishes	
Blueberry goby	*Lythrypnus dalli*	Q
Blackeye goby	*Coryphopterus nicholsii*	Q
Island kelpfish	*Alloclinus holderi*	Q
Blacksmith	*Chromis punctipinnis*	V
Senorita	*Oxyjulis californica*	V
Blue rockfish	*Sebastes mystinus*	V
Olive rockfish	*S. serranoides*	V
Kelp rockfish	*S. atrovirens*	V
Kelp bass	*Paralabrax clathratus*	V
California sheephead	*Semicossyphus pulcher*	V
Black surfperch	*Embiotoca jacksoni*	V
Striped surfperch	*E. lateralis*	V
Pile perch	*Damalichthys vacca*	V
Garibaldi	*Hypsypops rubicundus*	V
Opaleye	*Girella nigricans*	V
Rockwrasse	*Halichoeres semicinctus*	V
	Substrate	
Bare substrate		R
Substrates: rock		R
cobble		R
sand		R

B = Band transect
Q = Quadrat
R = Random point contact
M = 5m^2-quadrat
S = Size frequency measurement
V = Visual transect

Changes in scientific nomenclature

Patricia miniata	=	*Asterina miniata*
Astraea undosum	=	*Lithopoma undosum*
A. givverosa	=	*L. gibberosum*
Hinnites giganteum	=	*Crassedoma giganteum*
Allopora californica	=	*Stylaster californica*



Kettle pond on Cape Cod National Seashore. The 20 kettle ponds on the seashore are unioue geological and biological features that support many rare plants.

Photograph by John Portnoy.

Monitoring salinity in Hatches Harbor on Cape Cod National Seashore. By bringing back tidal flow, the diked marsh and its native vegetation are being restored.

Photograph by David Manski.

Monitoring at a fixed sample station in Kelp Forests of Channel Islands Park.

The R/S DELTA for monitoring underwater in Channel Islands National Park.

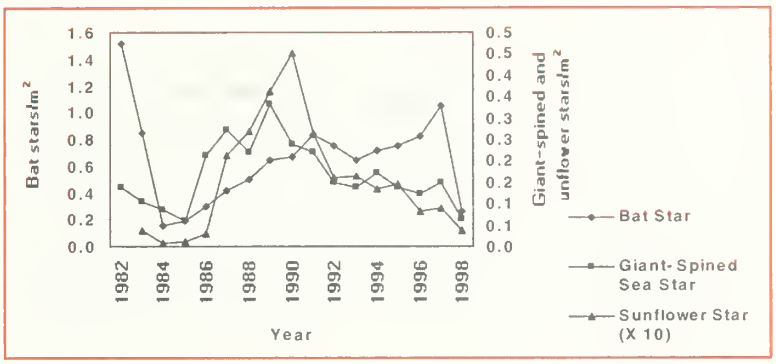


Figure 2. Mean density of sea stars. Channel Islands National Park, 1982-1998.

Santa Cruz and Anacapa Islands in 1996 and at Santa Barbara Island in 1997 revealed extremely low populations (1 ha^{-1}).

White abalone were proposed for listing under the endangered species act in 1999. The overall poor condition of abalone populations in southern California was reflected in the closure of all abalone harvest south of San Francisco in 1998, which followed closures for harvests of pink abalone *Haliotis corrugata*, green abalone *H. fulgens*, and white abalone in 1997, and black abalone *H. cracherodii* in 1993. The status of white abalone is generally thought to be the most perilous, but because their general habitat is at the fringe of or below typical scuba diving depths, little is known about them.

In 1999, 70 dives in the R/S DELTA were made to depths of 20-80 m to evaluate and categorize habitat and to count abalone. A total of 157 white abalone, 9 pink abalone, 1 flat abalone *H. walallensis*, and 3 red abalone were found during 76 h of diving with a submarine over approximately 58 km of suitable reef.

The overall mean density of white abalone was about 2 ha^{-1}. The density varied considerably between the different islands and offshore banks. The highest concentrations were at the most remote sites. Although the status of white abalone seems to be less devastating than it appeared in 1997, the density even in the hot spots does not approach densities of 800-4000 ha^{-1} in the 1970s. The current density is probably not enough to sustain the population.

The continued existence of the white abalone in California will require an increase in the current size of the population. The National Park Service in concert with the National Marine Fisheries Service, the California Department of Fish and Game, the U.S. Geological Survey, the University of California-Santa Barbara, the Scripps Institute of Oceanography, sand the Delta Oceanographics is developing a recovery plan. White abalone will be bred in aquaculture facilities, raise them to a size that will have the best survival capability, and place them on protected reefs in aggregations to boost re-establishment of wild populations.

Coral Reefs

Coral reefs are a beautiful natural resource, support diverse other beautiful biota, and provide natural protection of islands. In modern times, not only hurricanes but higher water temperatures, boat anchors and boat groundings, careless land use, dredging, pollution, and overfishing threaten the persistence of the reefs and have already caused severe deterioration. Monitoring provides information about the status of the reefs that is used to design protective measures from at least anthropogenic threats.

Since 1988, more than 350 tagged coral colonies at Buck Island Reef National Monument have been monitored annually and after every major storm. Records are kept on survivorship, growth, and disease resistance. Brain coral *Diploria strigosa*, mustard coral *Porites astreoides*, and star coral *Monastrea annularis* are the dominant live corals in the back reef and fore reef slope. The expansion of monitoring to two new elkhorn coral *Acropora palmata* colonies is planned.

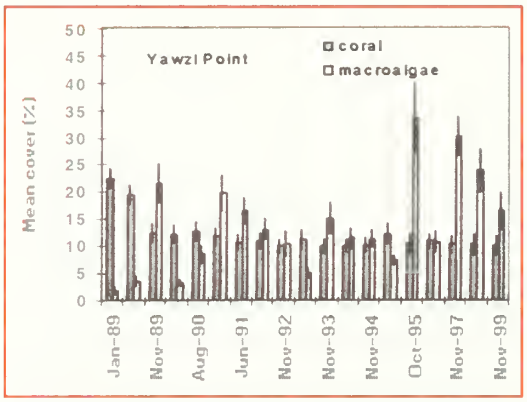


Figure 3. Densities of coral and macroalgae at Yawzi Point. Virgin Islands National Park, 1989-1999.

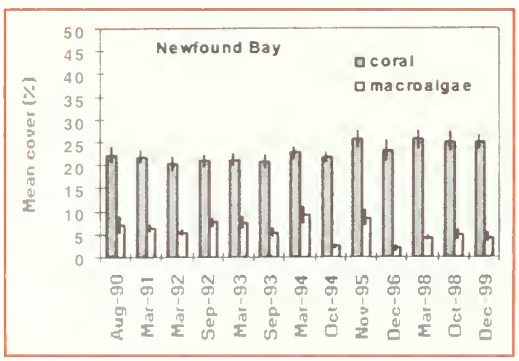


Figure 4. Densities of coral and macroalgae at Newfound Bay. Virgin Islands National Park 1990-1999.

Linear chain transects are used most often to quantify the amount of living coral cover and other substrate categories on Caribbean reefs. A light-weight chain is conformed to a reef along a measuring tape, and the number of chain links along each sessile organism or substrate type is counted and recorded. This method has been used for 10 years at Yawzi Point, for 9 years in the Newfound Bay, and semi-annually to annually in several sites at Buck Island Reef National Monument since 1988.

At Yawzi Point, the amount of live coral has declined, and the abundance of algae has increased (Fig. 3). The increase in algae is probably caused by a combination of increases in substrate availability after coral die-off (in part from damage by Hurricane Hugo in September 1989) and the inability of herbivorous fishes and sea urchins *Diadema antillarum* to keep algal growth in check. The reef in Newfound Bay was not damaged extensively by Hurricane Hugo, and live coral and macroalgae there have been stable since 1990 (Fig. 4). The percent of live coral at Buck Island Reef decreased most profoundly after major hurricanes in 1989, 1995, and 1998. In 1999, live coral and recruitment improved at some of the most severely damaged sites.

Terrestrial Vegetation

Grassland Plant Communities in the Great Plains

The future of native grasslands in the Great Plains is disconcertingly uncertain. Most of the tallgrass prairie and a significant portion of mixed-grass prairie have been converted to agriculture and other uses. Grazing by livestock and the suppression of natural fire caused the invasion by exotic species, encroachment of woody vegetation, and local extinction of native species. National parks in the Great Plains are small, species-rich islands in an otherwise depauperate landscape. The preservation of prairie remnants in the National Park System, including the complete restoration of disturbed sites and control of exotic and woody species, are management priorities of national parks in the Great Plains.

For several consecutive years, data on the composition and structure of grassland plant communities have been collected to establish a baseline of information. Future collections of data will be compared with the baseline information to determine the stability of the grasslands under National Park Service stewardship and to evaluate the effectiveness of prairie restoration. The collection of baseline information will be completed in 2000.

Homestead National Monument of America in southeastern Nebraska, a memorial to the pioneers who settled the West, is the site of one of the first prairie

Restored tallgrass prairie in Homestead National Monument of America.
Photograph by Lisa Thomas.

Monitoring the Missouri bladderpod in Wilson's Creek National Battlefield.
Photograph by Karola Mlekush.

Daisy-leaved moonwort in Great Smoky Mountains National Park.
Photograph by Jane Rock.

Rhododendrum wasted by a normally non-pathogenic fungus *Botryosphaeria* spp. in Great Smoky Mountains National Park.

Woody vegetation in Big Meadow, a natural opening in Shenandoah National Park.

Sword-leaved phlox is a rare endemic to the mountainous areas of West Virginia and Virginia. It occurs in Shenandoah National Park.

restorations. In 1939, seed and sod were transplanted into a 24.3-ha tract of severely eroding upland cropland. Haying and herbicide were used to foster the prairie until 1970 when prescribed fire was introduced. Seeding and sod transplantations have been continued. When long-term monitoring of restored plant communities was implemented in 1997, it revealed the occurrence of 21 previously unrecorded species in the monument. Species diversity in the restored prairie in the monument is now comparable to that in the most diverse remnant prairies in the prairie cluster (Fig. 5). Preservation of the restored prairie requires continued control of woody shrubs (mean cover = 18.65% in 1999) and exotic species, notably smooth brome grass *Bromus inermis* Leyss.

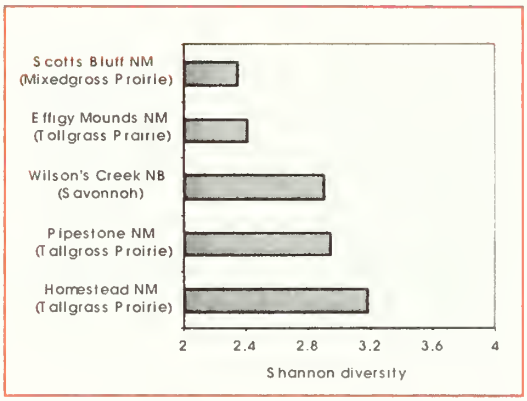


Figure 5. Shannon diversity of restored prairies. Great Plains Prairie Cluster, 1999.

The massive promontory in Scotts Bluff National Monument in Nebraska rises 244 m above the valley floor and was a landmark on the Oregon Trail. In 1996-97, 17 ha of formerly developed land were planted to mixed-grass prairie. Data from monitoring plant communities in adjacent sites were used to determine the composition of the seed mix. In 1999, seedling establishment was mixed. Needle-and-thread grass *Stipa comata*, Trin.; Rupr. was well established and occurred in 60% of the sample plots. However, transplants of the black-root sedge *Carex filifolia* Nutt. were ineffective, implying that alternative methods are needed for restoring this species (Table 6). Ruderal species, including some exotic species, are common 1-2 years after the implementation of restoration. However, an increase in the relative frequency of exotic species in the monument between 1998 (23.2) and 1999 (32.0) suggested the need for intervention (Table 7).

Big Meadow in Shenandoah National Park

Big Meadow is a 49-ha, ridge-top meadow along Skyline Drive in Shenandoah National Park. It is a natural opening with a wetland in the center. Rare plant populations, historic settlement sites, and the open character of the landscape impart natural and cultural values to the meadow. As the only large non-forested area in the park, the meadow is also a haven for wildlife and plants that need open habitat. Although the Meadow is only 0.06% of the size of the entire park, it supports populations of 18% of the state-listed rare plant species in the park and two state-listed rare animal species.

Since establishment of the park in 1935, woody vegetation has gradually encroached on the meadow and substantially reduced its size. Cost-effective management of the meadow that maintains the integrity of its natural and cultural resources and its esthetically pleasing appearance as a meadow is one of the many challenges in park management. In 1999, the vegetation inventory of the meadow that began in 1998 was completed. The collected baseline data describe the community composition and will be used to monitor the effects of management on the meadow's vegetation.

Combined data from 1998 and 1999 revealed that 17.6 % $\pm$ 3.6% (SE) of the meadow supported tall-shrub cover (> 0.5 m). Deerberry *Vaccinium staminium*, and male-berry *Lyonia ligustrina* dominated in the northern, western, and southern sections of the meadow, and panicled dogwood *Cornus racemosa* and broad-leaved spirea *Spirea latifolia* dominated in the wetland center. Low shrubs (< 0.5 m) covered 45.8% $\pm$ 7.9% (SE) of the meadow, and upland low blueberry *Vaccinium pallidum* was the majority of cover. The central wetland portion of the Meadow supported the highest coverage of high-shrubs. Low shrub cover was high in the central, southern, and northern meadow sections (Fig. 6).

Table 6. Seeding rate and establishment of dominant grasses. Scotts Bluff National Monument, 1999.

Species Scientific name	Species Common name	Seeding rate (pls lbs/acre)	Frequency %	Mean cover %
Stipa comata	needle-and-thread grass	2.5	60	11.88
Pascopyrum smithii	western wheatgrass	1	95	13.82
Koeleria macrantha	junegrass	0.56	0	0
Bouteloua curtipendula	side oats gramma	0.3	50	2.45
B. gracilis	blue gramma	0.26	55	0.95
Calamovilfa longifolia	sand-reed	0.21	20	0.5
Carex filifolia	black-root sedge	sod transplants	0	0

Table 7. Relative frequency of grasses by guild in restored mixed-grass prairie. Scotts Bluff National Monument 1998-1999.

Guild	Relative frequency	
	1998 %	1999 %
Seeded native grass	24.80	21.20
Exotics	23.20	32.00
Native forbs (not seeded)	18.00	11.80
Native grass (not seeded)	18.00	11.40
Seeded native forbs	8.80	6.90
Native annuals	4.80	16.70
Sedge (transplants	2.40	0.0

Burning, mowing, and shrub removal are scheduled in Big Meadow during 2000-2003 to stabilize the boundary, reduce shrub density, and improve rare plant habitat. The response of the vegetation to such management will be monitored.

Endangered, Threatened, and Rare Plants

Sword-leaved phlox *Phlox buckleyi* is a rare perennial that is endemic to the mountainous areas of West Virginia and Virginia. It is a federally and state listed endangered species. Plants typically occur in dry open habitats on gravelly soil and roadside banks. Soil disturbance, ill-timed mowing, and shading from adjacent vegetation threaten the survival of this species. Two populations of sword-leaved phlox occur on roadside banks in Shenandoah National Park.

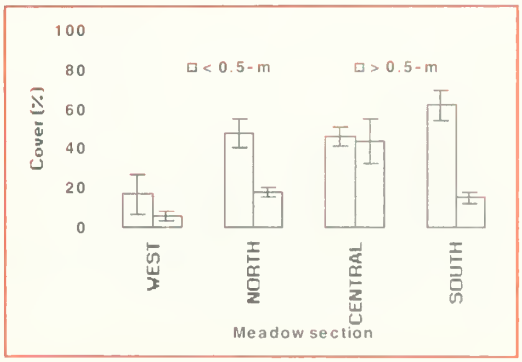


Figure 6. Average (% ± SE) cover of woody species that were shorter than 0.5 m and taller than 0.5 m in the four sections of Big Meadows. Shenandoah National Park, 1999.

Since their discovery in 1990, both populations have been periodically censused to monitor survival.

In 1998, population 1 consisted of 197 plants, but population 2 could not be found. On 28 April 1999, a wildfire destroyed 99% of the above-ground tissue of population 1. However, regeneration after the fire was excellent (Fig. 7). The final census in 1999 revealed 249 plants (about 30% seedlings, 70% nonflowering adult plants), 25% more than in 1998. In addition, 3 months after the fire, plants were sprouting in areas beyond the 1998 population boundary.

The increase in the number of plants and the expansion of the population are attributable to the fire. It removed leaf litter and reduced competition from surrounding herbs and grasses. Fire seems to stimulate regeneration of sword-leaved phlox. If the census in 2000 reveals a continuation of the favorable response by population 1 to the fire, the park may use fire to attempt re-establishment of population 2.

Three populations of the daisy-leaved moonwort *Botrychium matricariifolium* A. Braun a small, primitive fern, occur in Great Smoky Mountains National Park. This species is listed as significantly rare in North Carolina and as a species of special concern in Tennessee. One population of the three populations consists of 42 plants and the other two of 115 or fewer plants. Two permanent transects of 21-m and 10-m length were established at the smallest population (42 plants) in 1991 and plants within 3 m of each transect were mapped. Over the years, plants were doing well in locations devoid of leaf litter and duff. Because of a severe decline (67%) in the number of plants in 1997, the park began to manage the populations with fire and raking. Mapped plants were used as a guide for establishing three 7-m-x-10-m treatment plots (fire, raking, and no treatment) in March 1998. The population responded favorably to both treatments in 1999 when it increased from 23 to 114 plants (Figs 8-10). The number of plants in the control did not increase.

Bittercress *Cardamine flagellifera* O. E. Schulz, a stoloniferous perennial, is listed as threatened in Tennessee. Three populations occur in Great Smoky Mountains National Park; two are monitored because of threats. Baseline data were collected of one population in 1989, and the population was censused in 1991. In 1997, a decrease (16%) in rosettes caused concern (Fig. 11). A portion of the population was burned in September 1997 and the entire population was censused again in 1998. From 1998 to 1999, rosettes in the burned portion increased by 27%. The increase of fertile rosettes after the fire was twofold (118%; Fig.12).

Goldenseal *Hydrastis canadensis* L. is a highly valued perennial herb with thick yellow rhizomes. This plant was recently listed in CITES Appendix II and is listed as endangered in North Carolina and as threatened in Tennessee because of excessive collection and habitat loss. One population of two colonies (subpopulations 1 and 2) occurs in Great Smoky Mountains National Park. Data have been collected since 1989 (Fig. 13). In 1991, a native fungal disease, identified as *Streptobotrys streptothrix* was observed on the stems and leaves throughout the population. The infection was greatest in subpopulation 1, and the total number of stems decreased by 30% between June 1990 and June 1991. In September

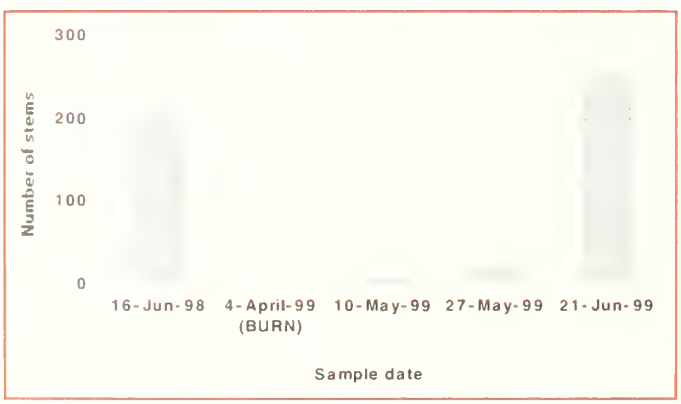


Figure 7. Number of stems in population 1 of the sword-leaved phlox before and after a fire in April. Shenandoah National Park, 1999.

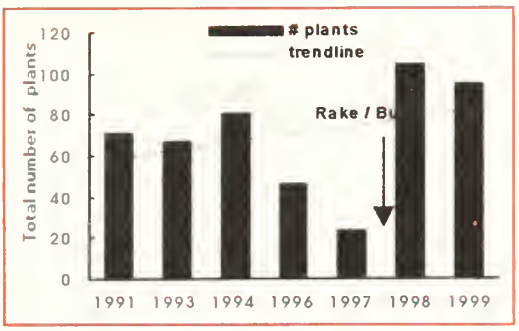


Figure 8. Number of daisy-leaved moonworts. Great Smoky Mountains National Park, 1991-1999. The number of plants increased after fire and raking.

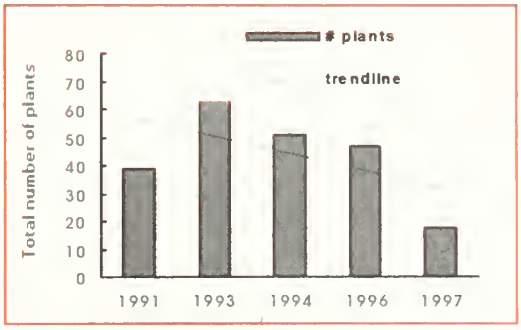


Figure 9. Number of daisy-leaved moonworts before fire. Great Smoky Mountains National Park, 1991-1997.

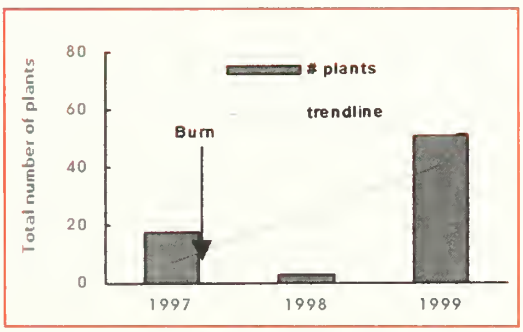


Figure 10. Number of daisy-leaved moonworts after fire. Great Smoky Mountains National Park, 1997-1999.

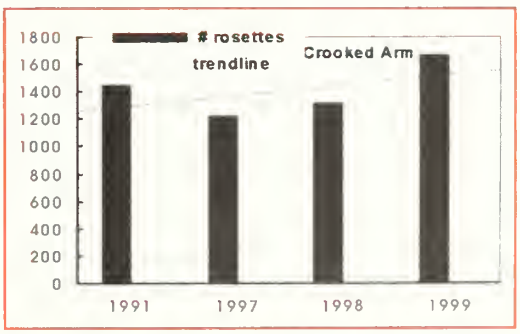


Figure 11. Number of bittercress rosettes in the burned portion of the population. Great Smoky Mountains National Park, 1991-1999.

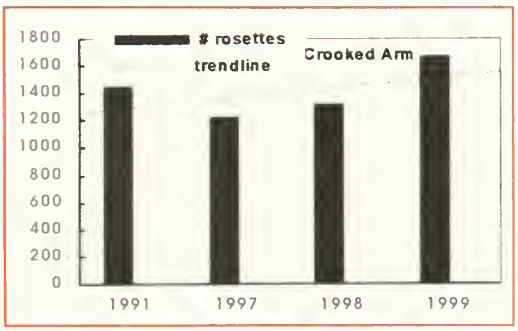


Figure 12. Number of fertile and sterile bittercress rosettes in the burned portions of the population. Great Smoky Mountains National park, 1991-1999.

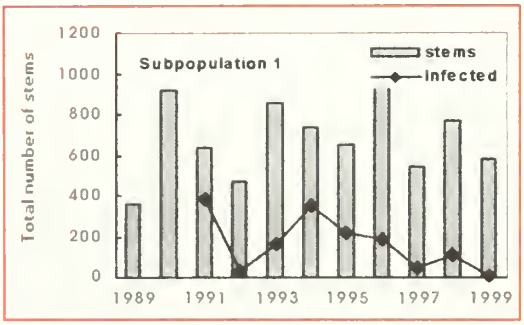


Figure 13. Total number of goldenseal stems and number of infected stems in subpopulation 1. Great Smoky Mountains National Park, 1989-1999.

1991, leaves and stems were clipped, bagged, and removed from both subpopulations. Leaf litter under the stems too was bagged and removed. The reduction in diseased stems (90%) in 1992 was noticeable, but diseased stems in subpopulation 1 more than doubled (110%) between 1993 and 1994 (Fig. 14). The incidence of disease decreased in 1995 without intervention and continued to decrease. In early spring 1998, the leaf litter was burned at subpopulation 1. The number of infected stems decreased by 93% between 1998 and 1999. Data indicate the treatments are effective.

The Missouri Bladderpod *Lesquerella filiformis* Rollins is a federally listed endangered plant that occurs in a narrow range of southwestern Missouri and northern Arkansas. It is restricted to limestone glades, which are sparsely vegetated grasslands with shallow soils and exposed bedrock. Approximately 60 populations are known in the range. One of the largest protected populations and three smaller populations occur in Wilson's Creek National Battlefield, Missouri.

Threats to Missouri bladderpod populations include woody encroachment of glade habitat by eastern red cedars *Juniperus virginiana* L. and invasion of exotic plants, notably three species of annual brome grass *Bromus racemosus* L., *B. sterilis* L., and *B. tectorum* L. Preservation of the bladderpod requires thinning cedars, controlling exotic brome grasses, and reseeding portions of the glade with native grass seed collected on site.

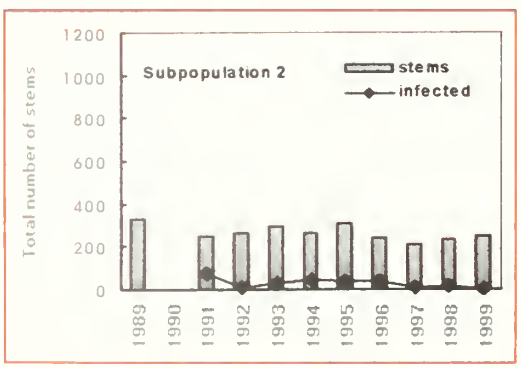


Figure 14. Total number of goldenseal stems and number of infected stems in subpopulation 2. Great Smoky Mountains National Park, 1989-1999.

The density of the largest Missouri bladderpod population in Wilson's Creek National Battlefield has been monitored since 1988. Each spring, stratified random sampling is conducted in a permanent grid of survey points in Missouri bladderpod habitat. The mean density of the Missouri bladderpod has ranged from 0 to 22 plants m^{-2} ($\bar{x}$ = 3.96 plants m^{-2}; Fig. 15). In the 1.38-ha area occupied by the population, the estimated population size has ranged from 0 to 303,400 ($\bar{x}$ = 54,679). In 1999, the mean density was 4.82 $\pm$ 2.35 (SE) plants m^{-2} (52 plots), and the estimated population size was 66 650 plants.

The size of one population of the Missouri bladderpod in Wilson's Creek National Battlefield has drastically fluctuated during 12 years of monitoring. Patterns of survival and fecundity have also varied among years and between glade microhabitats. Among four glade microhabitats—rocky glades, glades with mixed vegetation, glades with warm-season grass, and shaded glades—survivorship in 2 years of contrasting weather patterns varied by glade microhabitats. Annual differences in population size may have been related to variable weather conditions and to the interaction of weather and physical site conditions, including soil and litter depth in the glade microhabitats. Shallow soils and the exposed rocky and mixed habitats are more susceptible to drought and frost heaving. The two factors may be the cause of mortality of the Missouri bladderpod and its variable population size in spring. Indeed, soil temperature and moisture have substantially differed among the microhabitats. Daily soil temperatures during December through February revealed freeze-thaw cycles that indicated frost heaving. In five consecutive winters, the number of cycles was larger in the rocky habitat than in the other habitats (Table 8). The rates of soil moisture loss differed by microhabitat: 66% in shaded habitat, 75% in warm-season grass, 86% in mixed vegetation, and 87% in rocky areas. Soil moisture at the end of the drought period was less in the exposed microhabitats (rocky and mixed) than in the other habitats (Fig. 16).

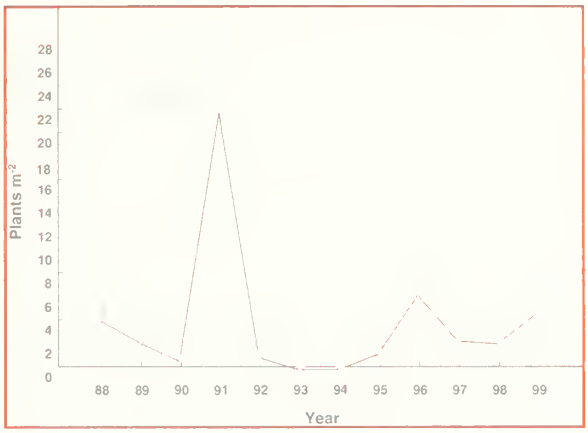


Figure 15. Mean density of the Missouri bladderpod. Wilson's Creek National Battlefield, 1988-1999.

Table 8. Number of freeze-thaw cycles among glade microhabitats in five consecutive winters. Great Plains Prairie Cluster 1995-2000.

	Soil freeze-thaw cycle (number)				
Habitat	1995-96	1996-97	1997-98	1998-99	1999-00[6]
RH[1]	6	3	3	8	11
MH[2]	3	2	0	0	0
WSGH[3]	1	0	0	2	0
SH[4]	M[5]	M[5]	0	0	0

[1]Rock habitat
[2]Mixed habitat
[3]Warm season grass habitat
[4]Shaded habitat
[5]Missing data
[6]December 1999 through January 2000

The western prairie fringed orchid *Platanthera praeclara*, Sheviak & Bowles is a federally listed threatened plant. A small isolated population occurs in a wet prairie-sedge meadow in Pipestone National Monument, Minnesota. In late spring, managers periodically set fire to the area where the orchid occurs to control the cool-season exotic smooth brome *Bromus inermis* Leyss, which has invaded the prairie. The last fire was set in late May 1997.

In July 1999, flowering western prairie fringed orchids were counted for the seventh consecutive year, and the presence or absence of flowering and nonflowering plants in permanently marked locations where orchids flowered in 1994 and 1995 was recorded. In 1999, 17 flowering orchids were found. Sixteen flowering plants had been found in 1994 after a prescribed fire (Table 9). The number of flowering plants is low after prescribed fires in the monument and elsewhere in Minnesota and Iowa. The number of orchids in the monument was largest 2 years after a prescribed fire in 1996. Also 2 years after a prescribed fire in 1999, the unexpected low number of flowering orchids may have been attribut-

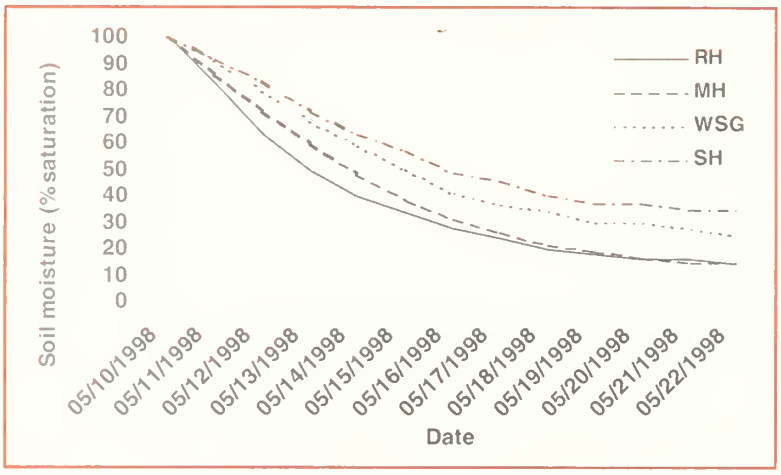


Figure 16. Soil moisture in glade microhabitats during a 13-day drought in spring. Wilson's Creek National Battlefield, 1998.

Table 9. Number of flowering western prairie fringed orchids by year and by date of previous fires in Pipestone National Monument, 1992-1999.

Year	Number of flowering plants	Date of previous fire	Number of years since previous fire
1993	33	May 1992	1
1994	18	May 1994	0
1995	37	May 1994	1
1996	55	May 1994	2
1997	3	May 1997	0
1998	0	May 1997	1
1999	17	May 1997	2

able to the date of the count. In the past, orchids in the monument flowered in the third week of July. In 1999, the orchids flowered in early July, at least 2 weeks before a count could be made. Because the count was made late, most orchids had completed flowering and some were probably not detected during the monitoring. The orchids may have flowered early in response to warm days. During May to mid-July in 1998, the weather station adjacent to the area where the orchid occurs, recorded above 32.2° C on only 1 day. In 1999, the temperature was above 32.2° C on 8 days.

The number of orchids was greater in 1999 than in 1994, 1995, or 1998. The increase in 1994 occurred after a declining abundance during 4 consecutive years and was similar to an increase in the fifth year of a population in the Sheyenne National Grassland, North Dakota (Table 10). In the same locations as in 1994, 5 non-flowering orchids occurred in 1998 but 3 non-flowering and 3 flowering orchids occurred in 1999. No orchids had flowered there since 1996. In the same locations as in 1995, 9 non-flowering orchids occurred in 1998 and 11 non-flowering orchids in 1999.

Table 10. Number and percent of flowering and non-flowering western prairie fringed orchids that were found again (relocated) after permanent marking in 1994 and 1995 in Pipestone National Monument and in 1987 in Sheyenne National Grassland.

			Number (%) of plants relocated after:				
Year	Site	Number marked	1 year	2 years	3 years	4 years	5 years
1994	Pipestone	18	13 (72)	9 (50)	7 (39)	5 (28)	6 (33)
1995	Pipestone	34	27 (19)	13 (38)	9 (26)	11 (32)	
1987	Sheyenne	160	88 (55)	44 (28)	25 (16)	17 (11)	22 (13)

The soft-leaved paintbrush *Castilleja mollis* is a member of the figwort family, Scrophulariaceae, and federally listed as endangered. The plant is a partially parasitic perennial herb with semi-prostrate branches that can reach 40 cm in length. The specialized bracts and calyx of this species are yellow to yellowish green and the leaves are gray, broad, and rounded. It may hybridize with the coast Indian paintbrush *C. affinis*, which looks similar. The host plant of the soft-leaved paintbrush seems to be goldenbush *Isocoma menziesii* var. *sedoides*.

The soft-leaved paintbrush is currently known from only two areas in Channel Islands National Park, California: on Carrington Point and Jaw Gulch on Santa Rosa Island. In 1996, as many as 1000 plants occurred in an area of less than 2 ha in the gulch. Several thousand plants occur on Carrington Point.

In 1996, browsing or trampling by herbivores had broken about 50% of the total number of stems of the plant in the Jaw Gulch and on Carrington Point. During 1995-98 in the Jaw Gulch, deer and elk uprooted and killed 59% of the plants and also seem to have harmed the reproduction of the soft-leaved paintbrush by the impairment of the host plant, goldenbush. After the cattle were removed in 1998, the number of plants with broken stems declined, particularly in the Jaw Gulch. The reduction in the deer herd had a similar result on Carrington Point.

Continued monitoring is expected to reveal a direct cause and effect, if any, by the reduction of exotic herbivores. An exclosure in the Jaw Gulch was erected in 1999 to further elucidate the effect of deer or elk on the soft-leaved paintbrush. Monitoring inside and outside of the exclosure will begin in late summer 2000. The future status of the soft-leaved paintbrush populations will be used to develop recommendations for allowable numbers of deer or elk on the island.

Gray birch *Betula populifolia* is an important component of one of the most unique and visible plant communities in Shenandoah National Park. Although it is a common pioneer tree of the northeastern United States, gray birch is rare in Virginia. A single population in the state persists near Big Meadow on a ridge top along Skyline Drive in the park. This population is believed to be a relict population from the last glacial retreat and may represent a unique genetic component of the species. Natural aging of the population and a lack of disturbance are attributed with widespread mortality of the birch and its suppression by oaks *Quercus* spp. and other tree species.

Gray birch is monitored to determine the status of its population and to describe the composition of the surrounding forest. The species is sampled in 25 randomly located nested plots in stands. Plot sizes of 4 x 100 m were used for trees, 2 x 20 m for saplings and shrubs, and 1 x 4 m for seedlings. Saplings and trees were placed into diameter and height classes. Stems of shrubs and seedlings were

counted, and seedlings were placed in height classes.

The gray birch population consisted of as many live (0.92) as dead stems (1.00). The stem density was equally divided between the three height classes, suggesting that the population is not even aged. Twenty-eight percent of the live stems supported basal sprouts, most of which were browsed by deer. No birch seedling regeneration was observed.

Gray birch had the highest stem density and frequency of occurrence of all tree species. Other frequently occurring trees included oak *Quercus* spp., black cherry *Prunus serotina,* and pine *Pinus spp.* The basal area was greater of oak species than of gray birch. Oak, hawthorn *Crataegus flabellata*, American hazelnut *Corylus americana*, and deerberry *Vaccinium stamineum*, dominated the understory. Hawthorn, cherry, and hazelnut dominated seedling regeneration.

The gray birch in the park does not seem to be in imminent danger of extirpation. However, mortality seems to be significant, and regeneration is not successful. Regeneration must be stimulated if the population is to be sustained. Fire kills above-ground stems of gray birch but stimulates vigorous basal sprouting and seedling germination. A prescribed fire is scheduled for one third of the population in fall 2000. The population description from this study will permit the quantification of changes in the birch population in post-burn sampling in 2001.

Forest Pests

In non-treatment areas in Great Smoky Mountains National Park, the density of the balsam woolly adelgid *Adelges piceae* on Fraser's fir is determined by examining the trunks of the firs in 100-cm^2 bark areas with 10x lighted magnifiers. Balsam woolly adelgid populations were lower in 1999 than in 1998 on untreated Fraser's firs on Balsam Mountain ($\bar{x}$ = 23.9 $\pm$11.4), higher on Clingmans Dome ($\bar{x}$ = 3.7 $\pm$ 2.8) and Mount LeConte ($\bar{x}$ = 15 $\pm$ 8.9), and about the same on Mount Sterling ($\bar{x}$ = 11.5 $\pm$ 10.2).

The butternut *Juglans cinerea* is an uncommon tree throughout its range. Butternut canker *Sirococcus clavigignenti-juglandacearum* is a fungal disease of unknown origin that began affecting butternuts in the late 1960s in Wisconsin. Because of the severity of the disease and the relative scarcity of the tree, the butternut was given a federal designation of a species of special concern. Seventy trees in Great Smoky Mountains National Park were tagged in 1987 and have been monitored by rating the crowns triennially with protocols of the U.S. Forest Service.

Forty of the original 70 trees, remain. In 1999, the number of butternuts in Class 1 (0-5 cankers), Class 2 (6-10 cankers), and Class 4 (16-20 cankers) increased. No butternuts were in Class 3 (11-15 cankers), and the number of butternuts in Class 5 (>20 cankers) decreased.

The increase in the number of trees in Class 1 was probably due to the healing of cankers on healthier surviving trees. The healed cankers may have been missed in the examinations. This does not mean that all trees are faring well. Only trees that receive full sun have the best chance of surviving. Reproduction is cyclical and any fruit that is produced must have full sun to survive. Natural disturbances such as floods and tree-fall are required for survival. Replacement trees were selected in 1996 to bring the total number of monitored trees to 69.

Rhodendendron maximum is a long-lived woody understory shrub that can form dense thickets. In 1993, patches of dead shrubs were observed in several areas of Great Smoky Mountains National Park. With the assistance of pathologists from the U. S. Forest Service and the University of Tennessee, a normally non-pathogenic fungus, *Botryosphaeria* spp., was identified as the most probable causal agent in combination with environmental stress such as drought.

Three health parameters—average number of leaf whorls over the whole plant, percent dieback over the whole plant, and percent chlorosis (yellowing) over the entire plant—are visually evaluated and equally weighted for an overall health rating, R. The health of the Rhododendron has not changed sig-

nificantly since 1995. Rhododendron will be evaluated again in 2001.

The hemlock woolly adelgid *Adelges tsugae* is a serious introduced pest in Shenandoah National Park that threatens to eliminate all stands of eastern hemlock *Tsuga canadensis*. First observed in 1988, it now occurs in all districts and at all elevations and aspects. After establishing sampling sites in 1990, park staff have monitored the hemlocks annually. Data from monitoring are used in related biodiversity research, environmental analyses, determination of management of the hemlocks, and particularly the control of the adelgid by various means. Although control of the adelgid is not feasible throughout the park, it is exercised in a few locations to preserve at least part of the hemlock gene pool in areas of historical, cultural, and natural significance that are accessible by road.

The density and the crown health of the eastern hemlock have significantly declined. In 1990-91, the percentage of live trees with excellent crown health was 84%. In 1999, the percentage of live hemlocks with excellent crown health was less than 1%, and 73% of the hemlocks had poor crown health. The mortality from the woolly adelgid increased from 8% to 41%.

For the determination of possible correlations between the landscape and the decline of the hemlocks, the park is supporting an analysis of data from 6 years of monitoring by the U.S. Geological Survey during 1993-98. The focus of the analysis is on a possible relation between the annual health of the hemlocks and the characteristics of the terrain or the environment in given stands. Already a correlation of elevation, terrain shape, and distance to streams with the decline of the eastern hemlock is apparent. The health of the hemlocks is worse at lower elevations, on warmer points of terrain, and closer to streams. The correlation suggests that environmental conditions are either controlling the hemlock woolly adelgid or making hemlock stands more susceptible to decline.

Fishes

Brook Trout

Brook trout *Salvelinus fontinalis* and other fish species in Shenandoah National Park are monitored annually in a representative suite of streams to obtain an understanding of the natural influences on fish population dynamics such as flood and drought, variations in stream water chemistry, and other factors that may either independently or collectively undermine the long-term stability of the populations. Native populations of brook trout provide good angling for park visitors and are one of the few resources that may be harvested in the park. Brook trout are also a key species in the ecology of park streams that may be at risk from a combination of anthropogenic and natural threats such as acid deposition, water flow extremes, and excessive harvest.

Streams in which fishes are monitored were stratified according to the three principal bedrock substrates in the park with different acid neutralizing capacity (ANC), the ability of stream substrates to neutralize acidic water. These streams include Paine Run, the Staunton River, and the Piney River, which typify low, medium, and high ANC. All other annual streams are equally stratified across the ANC gradient. Selected streams in the three gradients were further stratified by size (large, medium, small) and sampling sites were generally stratified by elevation (low, medium, high) along most streams. In 1999, fish populations were sampled in 49 sites along 24 streams. Three-pass electrofishing was used according to guidelines in *Standardized Sampling Guidelines for Wadable Trout Streams* by the Southern Division of the American Fisheries Society, to estimate fish population density and biomass.

Monitoring since 1996 revealed considerable variation in brook trout density (number of trout per 100 m^2) and biomass (total weight of trout in kg ha^{-1}) between years and between different sites in the same watershed. In 1999, the estimated density of brook trout ranged from 4/100 m^2 to 84/100 m^2 in a core group of 21 sampling sites stratified according to elevation, stream size, and ANC. The mean density from all sites was 31.2 100 m^{-2} (95% CI = $\pm$9.3). The estimated biomass from these sites ranged

from 8.9 to 129.8 kg ha^{-1} ($\bar{x}$ = 61.8, 95% CI = ±15.5). Trout density and biomass tend to be lower downstream at the lower elevation because of competition with increasing numbers and volumes of other fish species at water temperatures and conditions that are less suited for the reproduction and survival of brook trout.

In 1999, the estimated density of young-of-the-year (YOY) brook trout ranged from 8.2% to 100% per site. The pooled mean was 49.9% (95% CI = ±6.5). In recent years, the estimated proportion of YOY has fluctuated from 26% to 85% throughout the park. The year-to-year variation in the proportion of YOY is largely a function of egg and fry survival during the most critical period of October through March. In 1999, the estimated proportion of YOY was within the normal range for brook trout populations in mountain streams. There are observable differences in the estimated trout density and biomass between streams and their ANC (Figs 17-18). The pattern that emerged from 4 years of intensive monitoring indicates a drastic difference in trout biomass in particular between streams that have the lowest and highest ANC values. In 1999, the mean biomass ranged from 40.3 kg ha^{-1} (95% CI = ±9.9) in streams with low ANC to 90.8 kg ha^{-1} (95% CI = ±13) in streams with the highest ANC. In 1997, the estimated density was inflated throughout the park because of exceptional production and survival in the YOY age class. Between-year variations in trout density and biomass seem to be largely a function of year-to year fluctuations in annual production and survival as dictated by the timing and intensity of water-flow extremes.

The pH and ANC of streams in the park declined significantly between 1979 and 1991. Acidification and aluminum that is mobilized by acidification are toxic to fish. Although fish populations in streams with the lowest ANC are of concern, the estimated density and biomass of brook trout in those streams indicate relative stability over the short term. Other species, particularly blacknose dace *Rhinichthys atratulus* seem to be at greater short-term risk from the effects of acid deposition than brook trout. In Meadow Run, a stream with low ANC along the western slope, blacknose dace populations have gradually declined from mere trace levels to zero over 14 years. Otherwise, populations of brook trout and other fish species in streams with moderate and higher ANC seem to be stable and sustainable.

Reptiles

The Hawksbill and the Green Sea Turtle

The hawksbill *Eretmochelys imbricata* occurs in tropical and subtropical waters of the Atlantic, Pacific, and Indian oceans. These attractive reptiles have an elongated, oval carapace and overlapping scutes on the carapace (shell). The scientific name *imbricata* refers to these overlapping scutes. The carapace is brown and has numerous yellow, orange, or reddish brown splashes. The plastron (breast plate) is yellowish with some small black spots. The head of the hawksbill is small, the jaw is beak-like, and each flipper has two claws. The turtle's common name is derived from the bird-like or hawk-like shape of its beak or upper jaw. Hawksbills are omnivorous. They feed on a variety of organisms such as algae, mangroves, fish, barnacles, mollusks, sponges, and sea urchins. The turtles like shallow coastal waters around reefs and quiet bays where they forage on the bottom or in floating vegetation beds. All post-pelagic age classes favor coral reefs for feeding on sponges and for resting on ledges and in caves. The turtles also frequent rocky outcrops and shoals, which likewise are good habitat for sponges.

The length of the adult hawksbills ranges from 81 to 101 cm and the weight from 43 to 75 kg. Hawksbills may reach adult size in 15-20 years but may take 30 or more years to reach sexual maturity. Adult females reproduce every 2-3 years. In the Caribbean, the nesting season begins in May, peaks during July-September, and continues through December. The females lay several clutches in 2-week intervals. They bury their eggs in the sand under vegetation on beaches where hatchlings emerge after about 60 days. The hatchlings usually emerge at night. To reach the open water, the hatchlings emerge from the nest and head for the lighter horizon, which is over the sea.

The hawksbill has been a federally listed endangered species since 1970. The major cause of the exploi-

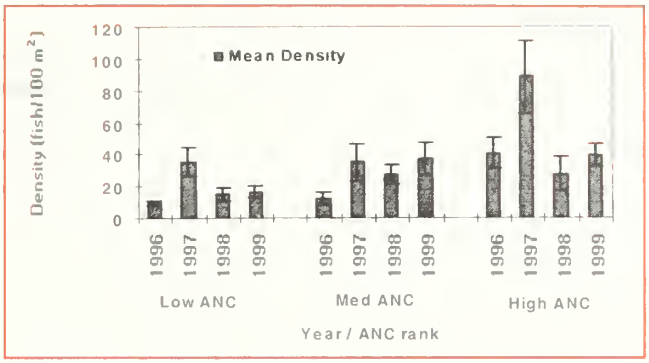


Figure 17. Average (± SE) density (fish 100 m^{-2}) of brook trout by ANC. Shenandoah National Park, 1996-1999.

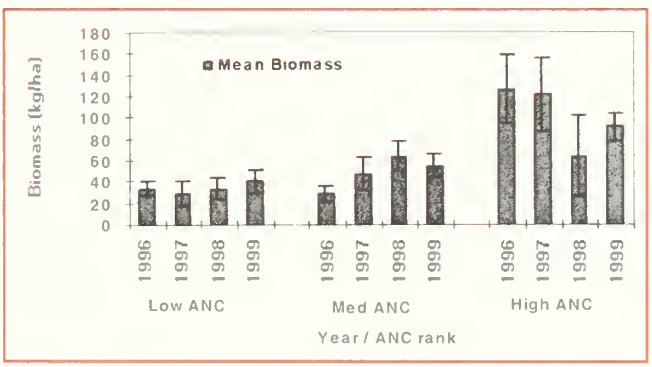


Figure 18. Average (± SE) biomass (kg ha^{-1}) of brook trout by ANC. Shenandoah National Park, 1996-1999.

tation of the species has been the demand for the tortoiseshell. Other causes are human consumption of the eggs, use of the skin for leather, destruction of nesting habitat by development and other anthropogenic uses of beaches, spearing of the turtles for sport and profit by scuba divers and snorklers, pollution, and loss of eggs and hatchlings to non-human predators.

The green sea turtle *Chelonia mydas* occurs in tropical and temperate oceans and seas. It occurs in fairly shallow waters and feeds in lagoons and shoals with an abundance of marine grass and algae. The females nest on open beaches with a sloping platform. The shell of the green sea turtle is shaped almost like a heart and is usually olive green to dark brown. The underside of the shell is white with some yellow-brown spots. The turtle has single-clawed flippers and a fairly small head. Its average curved carapace length is 100 cm, and its weight is about 170 kg. The diet of the green sea turtle consists mainly of marine algae and grasses but also includes jellyfish, sponges, and small mollusks.

The green sea turtle nests on the coast of Florida, in Puerto Rico, and in the U.S. Virgin Islands. It seemingly has a strong fidelity to nesting sites and often makes long-distance migrations between feeding grounds and nesting beaches. The nesting season

lasts from June to September. A female can lay as many as 7 clutches with 80-150 yolked eggs in a clutch. Incubation takes 48-70 days. Hatchlings generally emerge at night. The suspected age to maturity is about 20 to 30 years.

The green sea turtle has been a federally listed endangered species on the east coast of Florida and on the Pacific coast of Mexico since 1978. Elsewhere in its range, it is considered threatened. The turtle's status is attributable to consumption of eggs and turtles by people throughout its range, anthropogenic loss of nesting habitat, and accidental capture in fishing nets.

Monitoring and Status of Sea Turtles at Buck Reef Island National Monument

One of the most significant nesting areas of the hawksbill under the jurisdiction of the United States is in Buck Island Reef National Monument in the U.S. Virgin Islands. The nesting population in the monument has been monitored since the early 1980s and includes the tagging of adults and juveniles. The species is monitored throughout the year, but monitoring is intensified during the nesting season. From July to October, research staff and volunteers patrol the nesting beaches each night and record the activities of the turtles. Recorded data include site selection and fidelity, migration intervals, fecundity (clutch and egg size), carapace size, weight and growth of individuals, nesting and hatching success, and recruitment. Threats from predation, poaching, anthropogenic recreation, inundation by sea water, and desiccation are recorded. Very importantly, every effort is made to prevent harm to the eggs, and threatened clutches are relocated.

The protocol for collecting information on sea turtles, including the green sea turtle, on Buck Island Reef National Monument has been standard since 1988. Before then, beaches were patrolled on foot 2-3 times/week but only during daytime, and all sea turtle activities were recorded on standardized data sheets. Beginning in 1988, the beaches were also patrolled at night. Since then, nesting is recorded and nests are excavated during daytime from January to June and from October to December. Nesting is defined as any attempt to nest and consists of selecting the nest site and digging a cavity. If the female deposits a clutch into the cavity, she covers the eggs with the excavated substrate. During the peak of the nesting season of the hawksbills in July-September, the beaches are patrolled every night.

Information is collected on tagged and untagged nesting females, nesting, site selection and fidelity, migration intervals (in and between seasons), fecundity (number of clutches, egg size and weight), growth, weight, hatchlings (weight, size, number of scutes), and hatch success. To prevent impairment of hatch success, eggs are relocated if they are threatened by inundating seawater, erosion, desiccation, recreation, or predation. All clutches are monitored until hatching, at which time the nest is excavated to determine the extent of the hatch success and emergence success.

On Buck Reef Island Monument in 1999, the carapace length of adult hawksbills ranged from 81.6 to 101.4 cm ($\bar{x}$ = 89.2, n = 31), the carapace width from 61.3 to 86.7 cm ($\bar{x}$ = 77.8, n = 31), and the weight from 49 to 95 kg ($\bar{x}$ = 67.7, n = 28; Table 11). Only one green sea turtle was measured in 1999. Its carapace length was 115.9 cm, and its carapace width was 104.5 cm (Table 12).

The average clutch size of hawksbills in 1999 was 149 eggs (n = 79, range = 40-123). Twenty-six of 52 nests were relocated. The mean hatch success of clutches in the re-located nests was 48.4% (range = 08.5%-91.9%), and the mean emergence was 42.8% (range = 8.1%-91.9%%). The mean hatch success of clutches in the remaining nests was 58.4% (range = 0.7%-96.5%), and the mean emergence was 42.8% (8.1%-91.9%; Table 11).

The average clutch size of green sea turtles in 1999 was 142 eggs (n = 4, range = 128-150). all 4 nests were relocated. The mean hatch success of the clutches was 78.5% (range = 68.9%-86.7%), and the mean emergence was 75.6% (range = 68.2%-83.3%; Table 12).

Hurricane Lenny hit St. Croix and Buck Island Reef National Monument during the last days of the breeding season of the sea turtles on 17 November 1999.

Table 11. Characteristics of nesting hawksbills. Buck Island Reef National Monument, 1998-1999. CC L= curved carapace length, CCW= curved caraapce width.

	1998			1999		
Characteristic	*n*	Mean	Range	*n*	Mean	Range
CCL (cm)	26	90	80-97	31	89.2	81.6-101.4
CCW (cm)	26	80	68-86	31	77.8	61.3-86.7
Weight (± 2 kg)	24	67	50-84	28	67.7	49.0-95.0
Migration interval (years)	16	2	2-6	17	2	2-4
Number of clutches/female	27	2	1-4	31	2	1-6
Clutch size (number of eggs)	84	150	83-215	79	149	40-213
Hatch success of in situ clutches (%)	54	70.1	0-100	26	58.4	0.7-96.5
Emergence of in situ clutches (%)	54	67.6	0-98.0	26	48.9	0-89.9
Hatch success of re-located clutches (%)	23	53.7	0-90.0	26	48.4	8.5-91.9
Emergence of re-located clutches (%)	23	43.6	0-90.9	26	42.8	8.1-91.9

Table 12. Characteristics of nesting green sea turtles. Buck Island Reef National Monument, 1998-1999. CCL=curved carapace length, CCW = curved carapace width.

	1998			1999		
Characteristic	*n*	Mean	Range	*n*	Mean	Range
CCL (cm)	8	108.6	103.0-118.2	1	115.9	-
CCW (cm)	7	102.8	96.1-109.4	1	104.5	-
Migration interval (years)	4	2	1-4	1	1	-
Number of clutches/female	8	3	1-5	1	4	-
Clutch size (number of eggs)	19	112	77-150	4	142	128-150
Hatch success of in situ clutches (%)	10	64.5	0-97.5	-	-	-
Emergence of in situ clutches (%)	10	59.6	0-96.7	-	-	-
Hatch success of re-located clutches (%)	11	31.7	0-77.9	4	78.5	68.9-86.7
Emergence of re-located clutches (%)	11	29.5	0-77.9	4	75.6	68.2-83.3

Nevertheless, more than one third of the nests of the hawksbills and green sea turtles were affected. Thirteen of 51 nests were lost.

In 1999, 134 juvenile hawksbills and 11 juvenile green sea turtles were encountered by surveying snorklers (Table 13). Eleven of the hawksbills had no tags and were tagged.

Birds

Piping Plover

Since 1986, the Atlantic Coast population of Piping Plover *Charadrius melodus* has been a federally listed threatened species. The plover is threatened by the cumulative effects of habitat loss, human disturbance, and predation. On the Atlantic Coast, the Piping Plover breeds on coastal beaches from Newfoundland to North Carolina. The beaches of Cape Cod National Seashore support about 5% of the 1400 nesting pairs of the Atlantic Coast population. Pro-

tection of the plover on the seashore consists of temporal and spatial restrictions of off-road vehicles (ORVs), seasonally restricted visitor access to areas with nests, protection of nests from avian and mammalian predators with predator exclosures (mesh topped, welded wire structures), and public education about the status and management of the plover. The effectiveness of these measures is determined by monitoring the number of breeding pairs and reproductive success of the plover.

Beginning on 1 April 1999, the nesting and brood-rearing of 72 pairs of Piping Plovers were monitored on eight beaches on Cape Cod National Seashore. Eggs were first laid in the last week of April, and the number of occupied nests peaked during the last week of May and the first week of June. The birds used berm habitat for nesting 63% of the time and beach habitat 27% of the time. Nest loss in 1999 was the lowest since monitoring began in 1985. As a result, unlike in 1997 and 1998 when nest loss to overwash created a bimodal hatching pattern, hatching in 1999 was more closely synchronized and had only a single peak that occurred in the last week of June. Hatching success (number of hatched eggs) was 79%. Fledging success (number of fledglings) was 55%. Productivity (number of fledglings per pair) was 1.7 (Table 14).

Seventy-two pairs initiated 82 nests. No chicks were hatched from 16% of all clutches. Overwash, abandonment, and predation by crows *Corvus* sp. were the leading causes of nest loss. However, nest loss in 1999 was the lowest since observations began in 1985. Sixty-nine of 82 nests were protected with predator exclosures. Young hatched from 59 (86%) protected nests, 5 protected clutches were destroyed by overwash, and 5 protected clutches were abandoned by the adult birds. In the 13 unprotected nests, no chicks were hatched from 9 (69%) clutches because 3 clutches were lost to crows, 2 clutches to unknown causes, and 1 clutch each to overwash, abandonment, and unidentified avian predator. The eggs in yet another clutch were infertile.

This was the second year the Negotiated Rule for ORV management was implemented. At various times during the season, more areas were available to ORV travel. Twenty-three pairs of plovers nested in the ORV corridor. However, all but five of these pairs nested in the 6.4-km section of Race Point South Beach that was closed from 1 April to 22 July. More beach-closings than imposed by the negotiated rule were required. As a result, all but approximately 2 km of Race Point South Beach were closed for about 1 month. By 10 August, all of the ORV corridor that could legally be opened under the negotiated rule was opened except for the area between High Head and Head of the Meadow and the High Head access. This area was closed because of impassable beach conditions and the hazardous steep, scarped face at the High Head access.

Table 13. Number of juvenile hawksbills by size class, average carapace length (CCL), and weight. Buck Island Reef National Monument, 1998-1999.

	1998			1999		
Size class (cm)	Number	Average CCL (cm)	Average weight (kg)	Number[a]	Average CCL (cm)	Average weight (kg)
20-30	7	27.1	1.93	7	26.8	2.0
30-40	25	35.3	4.96	31	35.5	4.8
40-50	14	45.9	9.82	16	45.3	9.6
50-60	18	55.3	17.58	19	56.0	18.6
60-70	9	64.6	27.83	9	64.9	27.3
70-80	3	73.9	41.0	3	73.9	41.0

[a]Two of the captured juveniles were not measured or weighed.

Table 14. Number of breeding pairs of Piping Plovers, hatching and fledging success, and productivity by site. Cape Cod National Seashore, 1999.

Site	Pairs	Nests[a]	Laid eggs	Hatched eggs	Fledged chicks	Hatching success[b]	Fledging success[c]	Productivity[d]
Coast Guard Beach	14	16	51	40	21	0.78	0.53	1.50
Marconic Beach	10	13	39	25	11	0.64	0.44	1.10
Great Island, Jeremy Point[e]	12	13	48	40	30	0.83	0.75	2.50
Ballston Beach	5	5	19	16	11	0.84	0.69	2.20
High Head	1	1	4	4	4	1.00	1.00	4.00
Race Point Beach South	19	22	82	70	28	0.85	0.40	1.47
Race Point Beach North	3	3	11	4	4	0.36	1.00	1.33
Wood End, Long Point	8	9	35	26	14	0.74	0.54	1.75
Total	72	82	289	225	123	0.79	0.55	1.71

[a] Includes re-nesting.

[b] Total number of hatched eggs/total number of eggs.

[c] Total number of fledged chicks/total number of hatched eggs.

[d] Total number of fledged chicks/total number of pairs.

[e] Includes one nest that was not found until the chicks appeared on the beach. Not included in the number of laid or hatched eggs.

The number of nesting pairs and their productivity have increased since monitoring and management began. In 1985, the productivity of 18 pairs was 0.7. In recent years, the productivity of 60-80 pairs has ranged from 1.5 to 2.5. In 1999, the breeding Piping Plovers on the seashore represented about 14% of the population in Massachusetts and 5% of the entire Atlantic Coast population. In 1999, productivity on the seashore (1.7) compared favorably with productivity of the Piping Plover population in Massachusetts (1.5) and the entire population on the Atlantic Coast of the United States (1.4). The plover population on Cape Cod National Seashore represents a critical source population for the successful recovery of the bird.

Reproductive Success of Golden Eagles

Golden Eagles *Aquila chrysaetos* are the largest avian predators that nest in northeastern Denali National Park and Preserve. The understanding of the ecology of this species in North America is largely based on data from resident populations in temperate climates. However, Golden Eagles in northern North America are migratory and spend as many as 5 months migrating to, wintering in, and returning from temperate climates thousands of kilometers from their northern nesting areas. This life-history strategy is common to birds that breed in northern latitudes and creates high-energy demands for migration immediately before the breeding season. Furthermore, Golden Eagles arrive in their northern breeding areas in late winter when the abundance and diversity of their prey are at the lowest annual level. Therefore, productivity could be markedly lower in northern populations of Golden Eagles than in conspecifics in temperate climates.

In 1988, Denali National Park and Preserve began a comprehensive study of the ecology of its Golden Eagles. A major objective of the study was the documentation of reproductive characteristics of the species at high latitudes. Reproductive success of Golden Eagles in temperate climates is strongly tied to food supplies that are available immediately before egg laying. Therefore, a secondary objective was an examination of responses of Golden Eagles in the park to natural changes in the abundance of their late winter and early spring food sources, snowshoe hares *Lepus americanu,* and Willow Ptarmigans *Lagopus lagopus.*

From 1988 to 1999, eagles in the study area were surveyed from helicopters twice annually, once immediately after egg laying and once immediately before the fledging of young. Territorial and laying pairs of Golden Eagles were identified, fledglings were counted, and nesting success (the number of laying pairs that produce at least one fledgling). Data collection methods were designed in cooperation with personnel from the U.S. Geological Survey, Snake River Field Station, Boise, Idaho.

Indices of broad changes in the abundance of snowshoe hares and Willow Ptarmigans were obtained from observations during routine field activities. The observations were assumed to be comparable to an estimated abundance from spotlighting along transects as shown in a study with black-tailed jackrabbits *Lepus californicus* in Idaho.

Since 1988, the annual reproductive success of Golden Eagles in the park has been monitored in 56-76 nesting areas. In 1999, eagles in 76 pre-selected nesting areas were monitored. Occupancy rate of nesting areas in 1999 (93%) was higher than in all other years. Occupancy rates remained stable among all years, suggesting that the breeding population in the park is stable. In 1999, 77% of the territorial pairs laid eggs, which was 23% more pairs than in 1998. The success rate (the number of laying pairs that raised at least one fledgling) was 78%. This is higher than success rates in the preceding 2 years. In 1999, 71 fledglings were produced in the study area, more than twice the number in 1998. The mean brood size was 1.65, slightly higher than the 12-year average, and the overall population productivity was 1.00 fledgling per territorial pair.

In 1999, the number of snowshoe hares (8.12 day^{-1}) and Willow Ptarmigans (22 day^{-1}) in the study area was the highest since inception of the study. Annual indices of the abundance of snowshoe hares and Willow Ptarmigans highly correlated ($r^2 = 0.96$, $n = 12$ years, $p < 0.001$). Therefore, the mean number of snowshoe hares observed per field day was used as an index of prey abundance for examining

Piping Plover on Cape Cod National Seshore.
Photograph by Stanley Johnson.

Golden Eagle Chicks In Denali National Park and Preserve.
Photograph by R. Belous.

the response of reproductive success to changes in abundance of food supply. Overall, occupancy and success rates of the eagles were not affected by the changes in prey abundance. However, laying rates, success rates, and mean brood size vary in response to the abundance of hares. The laying rate (the percentage of territorial pairs that laid eggs) was the most important factor influencing the productivity of the Golden Eagles in the park. Between 1988 and 1999, laying rates varied widely and were closely related to the abundance of hares and ptarmigans. Overall, Golden Eagles nesting in northern latitudes produce smaller broods and fewer fledglings than eagles in temperate climates, and reproductive success of eagles in the park is strongly influenced by fluctuations in the abundance of prey in late winter or early spring.

Monitoring of Golden Eagles will continue in 2000. The development of a weather severity index to examine the relation between late winter and early spring weather and eagle reproduction is planned. In cooperation with personnel from the U.S. Geological Survey, Snake River Field Station, a protocol for the long-terming monitoring of Golden Eagles in the park will be completed. Cooperative research by the park, the U.S. Geological Survey, and the Oregon State University into environmental factors that influence reproductive success and survival of Golden Eagles will also be continued.

Breeding Bird Survey

The North American Breeding Bird Survey (BBS) is the most widespread program for monitoring the continent's breeding bird populations. The main purpose of BBS is the detection of changes in populations of all bird species encountered along a designated consistent route. A yearly index of relative abundance rather than a total number of breeding bird populations is derived from the survey data and can be used to determine trends over time.

In Denali National Park and Preserve, surveys are conducted from the Toklat Route and the Savage Route along the Denali Park road. On 14 June, 308 individuals of 29 different species were recorded along the Toklat route, and on 15 June, 362 individuals of 24 different species were recorded along the Savage route. A preliminary review of the data revealed no change in the numbers of individuals and species from previous years.

In the Great Plains, however, almost 70% of the 29 adequately surveyed grassland bird species have shown evidence of declining abundance during the past 25 years. Most native prairie in the Midwest and in the Great Plains has been lost, and remaining prairies are typically fragmented. The conversion to cropland and pasture, the removal or disappearance of native ungulates, the drainage of wetlands, and an increase in woody vegetation from plantings and fire suppression altered the grassland landscape of the Great Plains. Grassland loss and fragmentation caused changes in the abundance and distribution of grassland-associated vertebrates.

In 1997, the National Park Service identified a study of grassland birds as a high priority in the central region of the National Park System. The status of grassland birds in tallgrass prairie parks and other lands managed by the service is largely unknown. Information on current status and trends is essential for making informed decisions to protect, enhance, or restore grassland bird populations. The main objective of the study in 1999 was the inventory grassland-associated birds in two Great Plains parks.

In Agate Fossil Beds National Monument in 1999, 203 birds of 20 species were recorded from sampling stations and an additional 30 species outside the stations. Fifteen of the observed species (75%) were considered to be associated with grassland. The most abundant species in descending order were the Western Meadowlark, Lark Bunting, Grasshopper Sparrow, Red-winged Blackbird, and Lark Sparrow.

In Scotts Bluff National Monument in 1999, 232 breeding birds of 36 species were recorded from sampling stations and an additional 63 species outside the point the stations. Nine (25%) species were associated with grassland. The most abundant species were the Western Meadowlark, Common Grackle, Spotted Towhee, Black-billed Magpie, and Brown-headed Cowbird.

Monitoring Selected Species of Landbirds with Point Count Methodology in Denali National Park and Preserve, Alaska

The Alaska Bird Observatory has been a partner of Denali National Park and Preserve for long-term monitoring of land birds since 1992. The major focus is on the testing and development of methodology to quantify inter-annual variation in relative abundance of migratory and resident species of passerine birds and the detection of long-term trends in selected species of passerines. The primary objective of fieldwork in 1999 was the continuation of baseline monitoring of selected passerine species with point count methodology. Data were collected along 9 off-road routes and 2 on-road routes where surveys have been made since 1993, and along 2 off-road routes where surveys have been made since 1998. In 1999, surveys were made at 108 off-road point-count stations and 100 on-road point count stations. As in previous years, species richness was greatest between the Toklat River and Kantishna where sampling covers a greater number of habitats. The frequency of occurrence of most species remained relatively constant among years.

Prior to 1998, off-road surveys were conducted exclusively in forest dominated by spruce *Picea* spp. stands. During 1998, two off-road routes were added in alpine tundra and riparian habitat where many Blackpoll Warblers *Dendroica striata* were seen. This warbler is not common elsewhere in the park. The *Boreal Partners in Flight* designated the Blackpoll Warbler a priority species that should be considered in land-use plans, project planning, impact assessments, research, monitoring, outreach, and other activities.

Partners in Flight proposed national guidelines for all monitoring of birds by federal agencies. They suggested monitoring with a 90% probability of detecting a 50% cumulative or 2.74% annual decline in a species over a 25-year period. Under these national guidelines, species that occur at more than 14% of the point-count stations in the park can be monitored with a 90% probability of detecting a 50% decline over a 25-year period. If the current monitoring protocol and annual collection of data at 100 on-road point-count stations and 108 off-road point-count stations are maintained, 12 species of passerines in the park can be monitored commensurate with the guidelines. Preliminary analysis of data suggest that if the number of point counts in shrub, alpine tundra, and mixed-riparian habitat is increased, nine additional species including the Alder Flycatcher *Empidonax alnorum*, Gray-cheeked Thrush *Catharus minimus*, Arctic Warbler *Phylloscopus borealis*, Upland Sandpiper *Bartramia longicauda* , Spotted Sandpiper *Actitis macularia*, Horned Lark *Eremophila alpestris* , American Pipit *Anths rubescens*, Blackpoll Warbler, and Northern Waterthrush *Seiurus noveboracensis* may be monitored.

Mammals

The Island Fox

The island fox *Urocyon littoralis,* is a diminutive relative of the gray fox *U. cinereoargenteus* that is endemic to the California Channel Islands. It exists as a different subspecies on each of the six channel islands. The distinction is supported by morphology and genetics. The fox occurs on three of the islands in the park.

The estimated average number of adult foxes on San Miguel Island fell from near 500 in 1994 to less than 100 in 1997 (Table 15). Subsequent declines brought the estimated population size to fewer than 20 in 1999. Monitoring data from Santa Cruz Island and Santa Rosa Island indicate that declines of the island fox abundance is similarly catastrophic on those islands as well. Populations are so small that the species warrants listing as endangered under the Federal Endangered Species Act (Pub. L 93-205 as amended).

In a recent study of on Santa Cruz Island, predation by the Golden Eagle *Aquila chrysaeto,* was identified as the cause of death of 21 of 29 island foxes. In 1998, 4 of 8 radio-collared island foxes were killed by Golden Eagles in 4 months, and another 2 died of unknown causes. This high level of predation by Golden Eagles may be explained by the recent appearance of the birds as visitors on the Channel Islands in winter in response to a non-historic prey base of feral pigs *Sus scrofa*, the presence of breeding Golden Eagles as of 1999, and the absence of

Table 15. Estimated annual average (± SE) and island-wide density with 95% confidence interval of the island fox on San Miguel Island. Channel Islands National Park, 1993-1997.

Year	Average density	SE	Estimated island-wide density	95% CI
1993	7.89	0.27034	305	298-313
1994	11.26	1.16495	436	258-614
1995	7.88	0.95661	305	185-425
1996	2.61	0.87449	101	1-202
1997	1.80	0.72222	70	1-138

Bald Eagles *Haliaeetus leucocephalus*, which used to breed on the islands and may have kept Golden Eagles away. Moreover, on many northern Channel Islands, historic grazing by sheep changed the predominant vegetation from shrub to non-native grassland, which provides the foxes with much less cover from aerial predators.

Concerned about the potential loss of three subspecies of island foxes from its lands, the park convened a recovery team in April 1999 to develop strategies for the recovery of island fox populations to viable levels. The team concluded that:

- predation by Golden Eagles is the primary mortality factor now acting on the population
- disease or parasites may be compounding the effects of predation
- natural recruitment is low; and the most effective conservation measure that could be taken immediately is to increase survival of pups, juveniles, and adults by reducing or eliminating predation by Golden Eagles
- the fox population on the three islands is critically small, the animal's natural reproductive potential is low
- knowledge of all of the factors contributing to the population decline may be incomplete, and the effectiveness of proposed management of the Golden Eagle is uncertain
- establishment of a fox sanctuary and captive breeding program are necessary to safeguard individual foxes and to augment natural recruitment into the population.

Commensurate with the recommendations, the park in 1999 constructed 11 large pens on San Miguel and began capturing wild island foxes. As of December 1999, 14 island foxes were captured and placed in the pens. The 4 males among the captured foxes were paired with females. Only 1 fox is left in the wild on San Miguel Island. The park is currently constructing a similar facility on Santa Rosa Island.

The park and a cooperator, Santa Cruz Predatory Bird Research Group, are in the process of removing Golden Eagles from the northern Channel Islands. Sightings indicate that there may be as many as 3 breeding pairs and a total of 10-12 Golden Eagles on Santa Cruz and 2-3 Golden Eagles on Santa Rosa. In November, staff from the research group captured two Golden Eagles from Santa Cruz Island. The birds, an adult male from a breeding pair and an immature male, were relocated to the mainland and thus far have not left their relocation sites.

Population Trends of Wolves and Caribou

The management of the gray wolf *Canis lupus* is a major environmental issue not only in the recovery of threatened and endangered populations throughout the contiguous United States but also in Alaska and Canada where wolves are abundant and wildlife managers must address harvest and diverse other interests while managing predators and their ungulate prey in highly dynamic environments. The management of wolves is controversial, and members of the scientific community disagree about the role of wolves in limiting and regulating prey abundance below levels that are supported by forage, the importance of winter snowfall in wolf-prey relations, and the responses by wolves to changes in prey abundance or vulnerability. In Denali National Park and Preserve, wolves are an important high-profile, nonconsumptive resource.

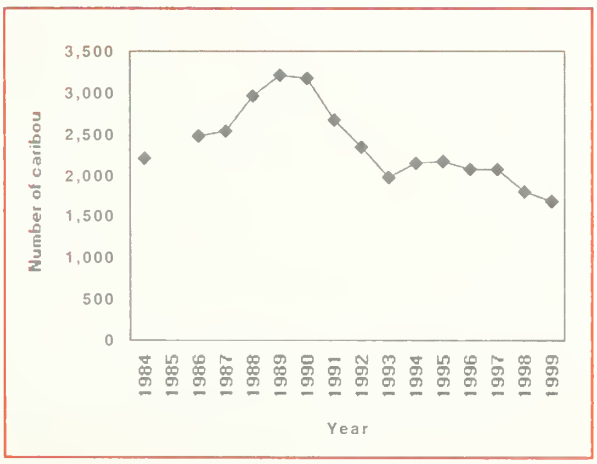


Figure 19. Trends in the populatin size of the Denali caribou herd. Denali National Park and Preserve, Fall 1976-1999.

Since 1998, the gray wolf in the park is monitored under the auspices of the servicewide I&M Program. The objectives are the determination of the status and trends of the wolf and caribou *Rangifer tarandus* populations and the evaluation of the dynamics and interactions of these species. Moose *Alces alces*, the other major prey species of wolves in the park, were recognized as a primary component of the predator-prey system. The work is performed by the Biological Resources Division of the U.S. Geological Survey as part of its study of the wolf in the park.

The wolves and caribou are monitored with standard radio telemetry that provides data for the estimation of the population size and information about the physical condition, distribution, age structure of the population, productivity, survival, and dispersal of wolves. The population dynamics of the caribou herd is determined from counts of adult cows on the calving ground that are made from a helicopter in late May and with surveys of herd composition that are made from a helicopter in late September. Data from heavily skewed toward older age classes, which may radio telemetry are used to estimate survival and to determine the distribution of the caribou.

Since 1986, the abundance of wolves and caribou has varied in response to variation in winter snowfall. During 1986-88, winter snowfalls were well below average. In 1986, the size of the Denali Caribou Herd was about 2600 animals and was increasing annually by about 7% (Fig. 19, Table 16). The abundance of the wolves—about 60 wolves in March 1986—was lower than expected based on the abundance of ungulates (Fig. 19, Table 17). Production was poor. and dispersal of young wolves was high.

The abundance of the wolves increased rapidly with the above-average winter snowfalls in 1988-94 and near-record snowfalls in winters of 1990-91 and 1992-93. The number of wolves reached 135 by late winter 1991 and stayed high through the 1992-93 winter. Production was high, and dispersal of young wolves substantially decreased during this period. The caribou herd reached 3200 animals in fall 1989 but declined to about 2000 by fall 1993. Recruitment of calves was poor at an average of only 12 calves:100 cows in September 1990-93 as compared to 35:100 during 1984-89. The mortality of cows increased from an annual 4% to 20%. The mortality of bulls also increased substantially, and

Table 16. Composition of the Denali caribou herd in late September and estimated herd size in fall. Denali National Park and Preserve, Alaska, 1984-1999.

Year	Cows > 1 YO[a]	Calves	Bulls	Calves:cows	Bull:cows	Herd size
1984	375	154	184	0.41	0.49	2200
1985	654	183	368	0.28	0.56	
1986	547	210	303	0.38	0.56	2470
1987	631	234	356	0.37	0.56	2540
1988	678	221	451	0.33	0.67	2950
1989	830	246	428	0.30	0.52	3210
1990	777	130	387	0.17	0.50	3180
1991	1067	72	409	~ 0.07	0.38	2660
1992	643	103	282	0.16	0.44	2340
1993	849	54	336	~ 0.06	0.40	1970
1994	648	253	253	0.20	0.39	2140
1995	685	204	204	0.19	0.30	2170
1996	820	243	243	0.13	0.30	2060
1997	777	228	228	0.16	0.29	2070
1998	718	87	205	0.12	0.29	1930
1999	667	92	261	0.14	0.39	1690[b]

[a]YO = year old

[b]tentative estimate

the adult sex ratio plummeted from an average of 56 bulls:100 cows during 1984-90 to 30:100 by 1995.

Winter snowfalls returned to average levels during the 1994-95 winter and the following years. The abundance of the wolves has declined with decreased abundance and vulnerability of their primary prey. The number of wolves was about 95 by March 1999 (Fig. 20, Table 17). Declines occurred as a result of lower production, higher dispersal of young wolves, and higher mortality of adults. The caribou population leveled off at about 2000-2100 animals during 1993-97 and declined to about 1700 by 1999. Production has remained low at an average of 14 calves:100 cows during 1994-99 (Table 16). The mortality of adult cows returned to 1986-88 levels after lower winter snowfalls but increased to an average of 12% during the last two winters. Because of the prolonged reduced recruitment, the age structure of the cow portion of the herd has become explain the increased mortality during recent winters.

Black Bears

Great Smoky Mountains National Park provides refuge for a significant portion of the black bear *Ursus americanus* population in the Southern Appalachian region. Because black bears require large tracts of land, they are excellent indicator species of habitat diversity, species richness, and biodiversity. Therefore, long-term monitoring of black bear populations provides not only information about the species but a better understanding of entire ecosystems.

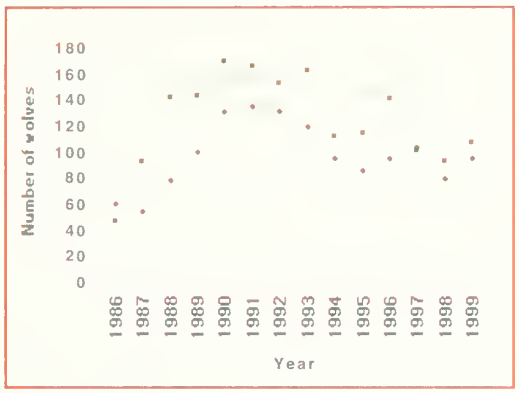


Figure 20. Trends in the population size of wolves. Denali National Park and Preserve, 1986-1999.

Black bears in the park are monitored by bait-station surveys to determine changes in relative densities and distribution and by a hard mast survey to determine the availability of important fall foods, namely acorns, and their influence on black bear population dynamics. Long-term monitoring by the University of Tennessee provides additional information. Annual mark-recapture has been conducted for 31 years (the longest ongoing monitoring of bears in the world) and provides the demographic information (sex and age structures, mortality, and natality) for estimating the annual population size.

During winter 1998-99, female bears were located in their dens. All of these females produced cubs, which is attributable to a good acorn crop from red oaks *Quercus* spp. during fall 1998. Unfortunately, the production of hard-mast by white and red oaks in 1999 was poor. It affected activities and movements of bears. Bears from the park were reported in portions of Tennessee, North Carolina, and northern Georgia. Increased movements of bears resulted in a slight increase of collisions of bears with vehicles. In response to the food shortage, black bear reproduction is expected to be low to non-existent during winter 1999-2000.

Visitation of bear bait-stations during 7-21 July ranged from 9.1% to 100%; overall visitation was 53.7% (Fig. 21). From 27 May to 5 August, 94 bears (61 males, 30 females, and 3 cubs of unidentified sex) were captured in 781 trap nights (8.0 trap nights per capture) by researchers from the University of Tennessee. A conservative estimate of the number of bears in the park is 1807 (95% CI = 482). Although this number is below the peak abundance in 1997, it represents a stable to slightly increasing population over 1998.

Funding was not provided to the University of Tennessee to support its long-term monitoring of bears in the park. The bait-station survey and hard-mast survey will continue.

Grizzlies

The grizzly *Ursus arctos* population in Denali National Park and Preserve is a naturally regulated component of a large-mammal predator-prey system that also includes wolves *Canis lupus*, caribou

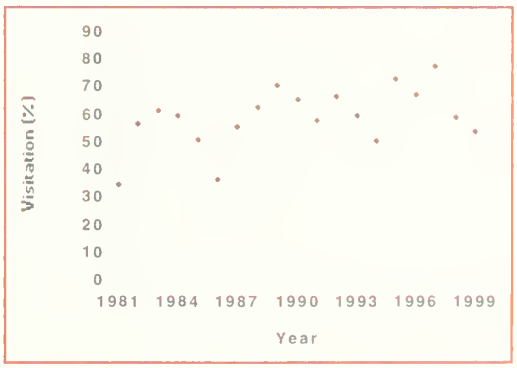


Figure 21. Percent of bait stations visited by black bears. Great Smoky Mountains National Park, 1981-1999.

Rangifer tarandus, moose *Alces alces*, and Dall sheep *Ovis dalli*. The grizzlies are an important visitor attraction but have not been harvested for at least 75 years. Adverse effects on the grizzlies from improved visitor access and intensive harvest of the bears outside of the park are growing concerns. Monitoring of the bears is expected to provide information about their status and trends, the dynamics of a naturally regulated grizzly population, and factors that are primarily responsible for such dynamics.

Table 17. Numbers of radio-collared packs, estimated density, and estimated total population size of wolve. Denali National Park and Preserve, Alaska, 1986-1999.

	Late winter (~15 Mar)					Fall (~1 Oct)				
Year	Packs	Wolves	Area (km^2)	Density per 1000 km^2	Estimated population size	Packs	Wolves	Area (km^2)	Density per 1000 km^2	Estimated population size
1986	4	26	7380	3.5	60	4	22	8180	2.7	47
1987	8	37	112125	3.1	54	9	70	13150	5.3	92
1988	14	69	15355	4.5	78	14	121	14670	8.2	142
1989	13	98	16810	5.8	100	11	127	15240	8.3	143
1990	10	106	13930	7.6	131	11	136	13930	9.8	169
1991	13	111	14275	7.8	135	13	137	14275	9.6	166
199-	15	103	13620	7.6	131	15	120	13620	8.8	152
1993	12	68	9900	6.9	119	12	93	9900	9.4	162
1994	10	61	11145	5.5	95	12	72	11145	6.5	112
1995	12	59	12120	4.9	85	11	80	12045	6.6	114
1996	11	69	12640	5.5	95	11	104	12776	8.1	140
1997	11	78	13080	6.0	103	12	75	12808	5.9	101
1998	12	61	13121	4.6	79	12	68	12578	5.4	93
1999	13	69	12578[b]	5.5[b]	95[b]	14	78	12578[b]	6.2[b]	107[c]

[a]Estimated population size is an extrapolation of the density in the study area to the 17 270 km^2 of wolf habitat in the park. The area of wolf habitat was determined by substracting areas above 1830 m (6000 ft) in elevation and large glaciers below that elevation from the area of the entire park.

[b]The estimated density in 1999 is tentative. It was calculated with the size of the area in fall 1998. Area used for density calculations each year is based on radio locationof the wolves s from 1 May in the previous year through 30 April in the following year (e.g., for 1997, area used during May 1996-April 1998) to ensure sufficient locations.

Grizzlies in the park are monitored along the north slope of the central Alaska Range in a 1750-km^2 area that was delineated after 2 years of tracking radio-collared bears. The boundaries of the area were determined by the bears' habitat-use patterns and important foraging habitats such as large, concentrated berry patches on glacial moraines. However, the area does not include the entire home ranges of all radio-collared bears. Elevations in the study area range from 600 m to 2000 m. The elevations are higher than in other study areas in the central Alaska Range because of the need to monitor the bears in habitats—including denning habitat—at such elevations. Summers in the study area are cool and wet with temperatures around 10-15° C . However, freezing and snow may occur during any month. Snow accumulation usually begins in October and dissipates from lowlands and sunny portions of foothills by mid-to-late May.

Bears are chemically immobilized by darts that are shot from a helicopter during May. A first premolar is extracted to determine the age of bears during their initial capture. Blood samples are collected to determine diet and exposure to diseases. Standard morphological measurements including weight are made to monitor growth and physical condition.

Production and the survival of dependent bears are determined by radio-tracking adult females from the time of den emergence to mid-October and by recording the number of cubs at heel. Survival rates of independent bears are determined by radio-tracking and observing such bears at least once during spring and fall.

During 23-24 May 1999, 13 grizzlies (10 females, 3 males) were captured. Retrieved were shed radio collars from 1 adult male and 1 adult female. Obtained were 221 radio locations of bears. Radio location was concentrated during spring. late-summer, and fall to measure production and annual bear survival to den entrance.

In 1999, 10 adult females produced 18 cubs. The average litter size was 1.8. Three adult females were accompanied by 4 yearlings. One adult female was accompanied initially by three 4-year-old males that dispersed during the breeding season. One of these males went east of the park boundary and was legally harvested. This harvest caused the only death (2.6% of the overall mortality) of an independent bear in 1999. Cub-of-the-year mortality was 67% and yearling mortality was 25%. Mortality in 1999 was similar to or smaller than the long-term annual mortality during 1991-98 (cubs-of-the-year 63%, yearlings 55%, independent bears 2%).

At present, 36 of the 38 radio-collared grizzlies are in the original study area. Eight of the 38 bears are independent males and 30 are independent females. Among the independent females, 24 are of reproductive age (6-years or older).

Moose

Moose *Alces alces* in Denali National Park and Preserve have been monitored since 1991 to collect long-term information for detecting or predicting changes in population dynamics. Information from monitoring will be used for the management and preservation of the animals. An aerial survey was conducted during 2-7 November 1999 to estimate the number of moose in a 7068 km^2 area of the park north of the Alaska Range. The survey area included the Eastern, Stampede, Kantishna Hills, and Slope regions.

A stratified random sampling technique developed by Gasaway and associates (Gasaway, W. C., S. D. DuBois, D. J. Reed, and S. J. Harbo. 1986. Estimating moose population parameters from aerial surveys. University of Alaska Biological Paper 22. 108 pp.) in 1986 was used to estimate the number of moose in the study area. Survey units followed those modified by Fox in 1997. The aerial stratification process described by Gasaway et al. was modified by stratifying survey units based on the number of moose observed in the same or adjacent units during previous surveys and habitat characteristics (e.g., proportion of trees, topography). With these criteria, survey units were assigned to one of two density strata, a high-density stratum of $\geq$0.3 moose km^2 and a low-density stratum of <0.3 moose km^2 (Table 18). Survey data were analyzed with MOOSEPOP. Population estimates are reported with $\pm$90% CI.

The survey was made in 72 units (37 high-density units and 35 low-density units) that comprised 2,405 km^2 (34%) of the study area (Tables 18-19). Snow conditions were moderate to good throughout the survey area (Table 20). Only 145 moose were seen during standard searches at an overall sightability correction factor of 1.11. Intensive searches were made in 25 high-density units (849 km^2); 161 moose were seen. A total of 924 moose were seen. The estimated number of moose in the entire survey area was 1,866 ± 244. The calf:bull:cow ratio was 22:69:100. Calves were 12%, bulls were 36%, and cows were 52% of the estimated population. An estimated 80% of the cows was without calves; 19% of the cows had 1 calf, and 2% of the cows had 2 calves.

The estimated overall density of the moose was 0.26 km^{2}. The observed moose density was 3.2 times greater in high-density survey units (0.58/km^2) than in low-density survey units (0.18 km^{2}). The observed density of moose in survey units ranged from 0.0 km^{2} to 1.8 km^{2}.

The estimated number of moose, calf:cow ratio, and bull:cow ratio in the study area have remained relatively stable since 1986 (Table 21). In 1996, the bull:cow and calf:cow ratios included data from moose in the Lakes and Flats regions of the park, which comprised 8% of the total population during that year.

Black-tailed Prairie Dogs

Prairie dogs *Cynomys* spp. once inhabited an estimated 10%-20% of the short and mixed-grass prairies of the United States. Now they may inhabit only 2% of their historic range. The number of black-tailed prairie dogs *C. ludovicianus* may have increased in the late 1800s because of heavy cattle grazing but has since substantially declined. The proximate causes of the declining abundance of prairie dogs include disease, agricultural practices, and urban

Table 18. Number of units and area (km^2) by strata for survey of moose. Denali National Park and Preserve, November 1999.

Number of units	High-density strata	Low-density strate	All strata combined
Available	37 (287)	167 (5781)	204 (7068)
Used	37 (287)	35 (1239)	72 (2526)

Table 19. Number of observed moose by sex, age class, and strata and estimated population size (±90% CI). Denali National Park and Preserve, November 1999.

Sex and age class	High-density strata	Low-density strata	All strata combined	Estimated population size
Cows	419	99	518	979 ± 131
Calves	72	26	98	215 ± 43
Bulls	227	81	308	672 ± 112
Combined	718	206	924	1866 ± 244

Table 20. Classification of snow conditions for sightability of moose during aerial surveys (from Gasaway et al. 1986.)

Age of snow classification	Coverage	Snow ranking
Fresh	Complete	Good
	Some low vegetation showing	Moderate
	Bare ground or hevbaceous vegetation showing	Poor
Moderate	Complete	Good
	Some low vegetation showing	Moderate
	Bare ground or hevbaceous vegetation showing	Poor
Old	Complete	Good
	Some low vegetation showing	Moderate
	Bare ground or hevbaceous vegetation showing	Poor

Table 21. Ratios of moose cohorts and estimated population size (±90% CI) in the Eastern, Stampede, Kantishna Hills, and Slope regions. Denali National Park and Preserve, 1986-1999.

Year	Calves/100 cows[a]	Bulls/100 cows	Estimated populatin size	Source
1986	23	75	1650 ± 347	Meier 1987
1991	23	81	1564 ± 123	Meier et al. 1991
1996	30	56	2000 ± 402	Fox 1997
1997	22	63	1630 ± 204	Belant and Stahlnecker 1997
1999	22	69	1866 ± 244	This study

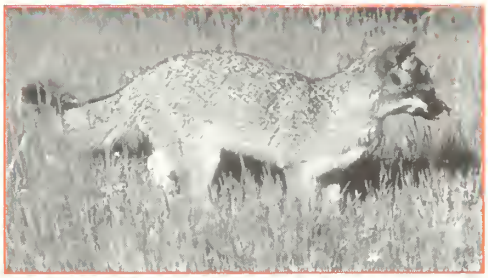
development. Additionally, sylvatic plague *Yersinia pestis* was introduced into North America and presumably causes massive mortality in prairie dogs.

Black-tailed prairie dogs used to inhabit 12 National Park System units but during the past 20-40 years have been extirpated from 5 units south of the Colorado-Kansas border. The extirpated populations seemingly were small relics of larger populations that were subjected to intensive control. Stochastic effects on diminished populations may have attributed to the extirpation.

During summer 1995, monitoring protocols and digital-mapping technologies were developed to determine the distribution and abundance of black-tailed prairie dogs in seven parks in the Great Plains, including Scotts Bluff National Monument, Nebraska. The colony size and density of the black-tailed prairie dogs in Scotts Bluff National Monument steadily increased during 1996-98 (Table 22). In 1999, the population size more than doubled, and the animals occupied 3.2 times more area than in 1998.

Table 22. Distribution and abundance of the black-tailed prairie dog in Scotts Bluff National Monument, 1995-1999.

Year	Colony size (ha)	Density (prairie dogs/ha)	Population size
1995	1.4	14.2	19.9
1996	1.4	24.0	33.6
1997	2.6	33.6	87.4
1998	3.3	28.2	92.4
1999	10.5	23.6	247.4



Island Fox in Channel Islands National Park.

Caribou in Denali National Park and Preserve.
Photograph by Penny Knuckles.

Black-tailed Prairie Dog in Scott's Bluff National Monument.
Photograph by Lisa Thomas.

Data Management in the I&M Program

The Inventory and Monitoring Program invests significant resources for information management. Information resource management projects funded by the I&M Program include databases and information systems that support ecological monitoring and natural-resource inventories. I&M information resources include desktop- and Internet-based databases, network infrastructure development, traditional and World Wide Web publications, training for natural-resource managers, GIS data and application development, and acquisition, cataloging, and archiving of resource data. In addition, I&M staff are working on integrating natural-resource data holdings internally within the program and externally with other NPS cooperators.

Bibliographic Databases

The Natural Resource Bibliography (NRBIB) and the Geologic Resources Bibliography (GRBIB or GeoBib) are bibliographic databases funded and supported by the I&M Program. As discussed in more detail below, the two bibliographies share a common Procite format but have distinct data types and origins. NRBIB contains a catalog of document holdings for parks including internal NPS and gray literature, whereas GRBIB consists of a bibliographic index of reference publications, most of which do not reside in parks' holdings. Although similar in data structure, the two databases have been developed as separate bibliographic systems. In FY 2000, the I&M Program will have a contractor integrate NRBIB and GRBIB into a single bibliographic system that accommodates the data types and needs of both these and other resource-related bibliographic databases.

Natural Resource Bibliography

NRBIB is a set of annotated bibliographies of park-specific natural-resource information, especially park document holdings, that have been completed by the I&M Program for each of about 250 National Park System units. The NRBIB database contains more than 100,000 bibliographic citations. The initial inventory compiled park bibliographies into park-based Procite databases. Subsequently, the park databases were aggregated into a single Internet-based bibliographic system in Lotus Notes that is currently accessible at http://www.nature.nps.gov/nrbib. In FY 2000, NRBIB will be converted from Lotus Notes to Oracle, which will also be Internet accessible. Long-term issues include keeping the park citation lists current, making park bibliographies fully accessible online, addressing concerns about sensitive information contained or referenced in citations, and providing assistance to users (e.g., with data entry and searches). To address these issues, the I&M Program is currently funding an interim NRBIB coordinator position stationed at the Columbia Cascades Support Office Library. A permanent Bibliographic Coordinator position is planned for the Natural Resource Information Division in FY 2001.

Geologic Resources Bibliography

GRBIB contains a bibliographic index of park-specific earth-science reference documents that are being compiled for the NPS Geologic Resources Inventory. When complete, GRBIB will contain about 100,000 references. The initial bibliographies were developed for each park in Procite format by the U.S. Geological Survey from searches of the Georef and Geoindex databases. Park bibliographies are being aggregated into an Internet-based bibliographic system in Lotus Notes at http://165.83.36.151/biblios/geobib.nsf (login: geobib read, password: anybody). For compilation, the databases must be converted and edited for validity and duplicate citations. After validation, lists of geologic map references are created and used to develop geologic index maps. Bibliographies for 31 parks are complete, and data for an additional 19 western parks are ready for validation. In FY 2000, GRBIB will be converted from Lotus Notes to Oracle, which will also be Internet accessible.

NPS Species List Database

The I&M Program is developing a species database, called NPSpecies, to document the present, past, or probable occurrence of vertebrates and vascular plants in NPS units. In FY 2000, the project is acquiring, compiling, and verifying existing species data from parks and from national databases and institutions such as museums and herbariums. Subsequently, the I&M Program will fund park projects to augment the initial data acquisition with local records, voucher specimens, and additional field investigations. The current goals are development and popu-

lation of an Microsoft Access version of the database for immediate distribution and contracting development of a master Internet-based version in Oracle. The Oracle database will link to NRBIB and include different levels of user access (public to administrative) to ensure data integrity and to restrict access to threatened- and endangered-species information. Final database development, online availability, and systematic downloads of integrated versions of software and data should be completed during FY 2001. The two major categories of information in NPSpecies are a species checklist and the supporting evidence. Each park's species checklist includes important data such as federal and state threatened and endangered status, TNC Global Rank, abundance, residency, and nativity. The three forms of supporting evidence include (1) references such as journal articles or reports, (2) voucher specimens from park or other collections, and (3) optional observations documented by each park. The observations table is included for parks to document wildlife observation records, cards, and field notes if desired.

NPSpecies and the Integrated Taxonomic Information System (ITIS)

ITIS serves as the taxonomic authority for federal agencies and the NPSpecies database. ITIS is an interagency database for the compilation of reference species data for comparison and sharing throughout North America (see http://www.itis.usda.gov/plantproj/itis/index.html for more information). Each species in ITIS has a unique Taxonomic Serial Number (TSN) that links to the various synonyms and historic names of the species. A network of taxonomic experts reviews and revises taxonomic names in ITIS, documents new names, and assigns TSNs to new species, subspecies, hybrids etc. Most functions in NPSpecies are dependent on the TSN assigned during data entry. NPSpecies includes an ITIS search form and a data-entry form to enter species that may not yet be included in ITIS. In addition to ITIS references, the NPSpecies database also allows parks to maintain their own nomenclature.

Monitoring Protocols

Long-term ecological monitoring is an integral component of the I&M Program. I&M staff assist parks and monitoring networks with planning, funding, development, documentation, and implementation of monitoring protocols and projects. The World Wide Web site Monitoring Natural Resources in Our National Parks (http://www1.nature.nps.gov/sfancy) provides information to parks for designing and implementing long-term monitoring of natural resources. The website is updated regularly and integrates links to numerous other web resources and documents related to inventory and monitoring. In addition, the site includes a database of monitoring protocols developed by NPS units and other agencies that conduct ecological monitoring. The protocols database identifies each monitored resource and includes the responsible park or agency, project status, primary references, brief project description, and any available link to online documentation. The protocols database contains records from 58 monitoring endeavors.

Dataset Catalog

The I&M Information Resource Dataset Catalog is a database system in which NPS units may record the existence and availability of all types of resource data. The Dataset Catalog documents abbreviated metadata about a variety of data sets--from physical files and photographs to digital scientific and spatial data. Concise one to two-page input and report forms provide a straightforward way to document resource data that may or may not meet formal metadata standards. Currently, the Dataset Catalog is available as an Microsoft Access database (http://www1.nature.nps.gov/im/datacat\download.htm) and as an Internet-based system in Lotus Notes (http://165.83.36.151/parksvc/dcat.nsf, login: dcatread, password: anybody). To date, the Internet-based Dataset Catalog has mostly been used by the I&M Program to catalog CD-ROM products acquired from the Base Cartography inventory. The online database currently contains more than 6000 metadata records for about 265 NPS units. During FY 2000, the database structure will be revised, a new MS Access application will be developed, and the Internet-based system will be revised and migrated to an Oracle system. The revised

Dataset Catalog will contain several new or revised fields, and the structure will generally map to an abbreviated FGDC formatted metadata file. The revised database will accommodate records from the existing versions, but because of the revision, the completion of imported records will need some additional editing. The new versions will be available or distributed to support development of the 32 new I&M Program-funded ecological monitoring networks.

GIS Data Browser and Internet Service

In conjunction with the Alaska Support Office and NPS GIS coordinators, the I&M Program is developing an ArcView GIS Data Browser to facilitate the distribution and use of spatial data and other digital products associated with the natural-resource inventories. Resource inventories that produce spatial data include base cartography, geology, soils, species distribution, vegetation, and water quality. Implemented as an ArcView extension, the browser extends ArcView's functionality with additional geographic projection support, a customizable theme picker dialog, predefined and formatted names and legends, interactive graphics and textual descriptions, online metadata and reports, and standardized directory structure. The browser's standardized interface, nomenclature, and structure will allow servicewide consistency and compatibility of data. The ArcView Browser should be ready for delivery to parks by about June 2000. In addition, I&M will develop and deliver ArcView- and browser-ready spatial data and digital information as the standard product from its inventories. I&M staff plan to process and deliver digital base cartographic data and ArcView Browsers to about 50 parks in FY 2000. Data acquisition and preparation for the ArcView Browser include a project with the North Carolina State University to convert and develop standard metadata for GIS coverages developed as part of the Baseline Water Quality Inventory for more than 180 parks. Other FY 2000 I&M projects are developing network infrastructure and compiling a comprehensive set of GIS data for NPS units onto a dedicated computer system that will serve GIS data and applications over the Internet.

Digital Inventory Reports

In conjunction with development of the ArcView GIS Data Browser discussed above, the I&M Program is developing a standard digital report format that allows interactive use with a variety of computer software. In general, natural-resource inventory reports will be converted and published digitally as Microsoft Windows Help files. Digital reports will be developed for each of the natural-resource inventory products if practicable and applicable. In FY 2000, the I&M Program is funding the conversion of about 185 existing Baseline Water Quality Data Inventory and Analysis Reports from disparate digital and analog formats to Microsoft Word 97 and Microsoft Windows Help formats. The water quality reports draw on existing Environmental Protection Agency (EPA) databases, particularly STORET, the national water quality database, and will be completed for all NPS units with significant water resources. The reports are a comprehensive inventory of all water quality data; descriptive statistics and graphics characterizing annual, seasonal, and period-of-record central tendencies and trends; and comparative analysis of park data with relevant EPA national water quality criteria and NPS-75 Level I water quality parameters. The entire report (text, tables, and graphics) and all databases (water quality data; hydrography; and water quality station, water gage, facility discharge, drinking intake, and water impoundment locations) will be converted and delivered with the ArcView Data Browser.

Publications and World Wide Web Resources

The World Wide Web home page of the I&M Program (http://www1.nature.nps.gov/im/index.html) links to the electronic copy of Natural Resource Inventory and Monitoring in National Parks brochure. The brochure features general information about the natural-resource inventories and long-term environmental monitoring in the National Park Service. In addition, the I&M Program home page links to fact sheets, ecological monitoring information, the draft Data Management Protocols, and the I&M Program annual reports. The publications webpage of the Natural Resource Information Division links to an index of fact sheets (http://www1/nature.nps.gov/pubs/ facts/findex.htm) which describe the status of each inventory. As discussed above, the link to

Monitoring Natural Resources in Our National Parks (http://www1.nature.nps.gov/sfancy) provides information to parks for designing and implementing long-term monitoring of natural resources. The webpages of the I&M Program also link to partners and other NPS entities associated with inventory and monitoring. In addition to program information, I&M staff also provide online access by the public to selected inventory data. Public access is available to the Monitoring Protocols, Dataset Catalog, and Bibliography databases discussed earlier.

Data and Information Integration

The integration of data and information is an important goal of the I&M Program and of the NPS in general as stipulated in the NPS Strategic Plan, Goal Iva1, Integrating and Interfacing our Major Data Systems. I&M staff are planning to integrate several I&M databases and data resources during FY 2000. Most systems with tabular data will be integrated as part of development and migration to Oracle, whereas most spatial data and attributes will be integrated in the ArcView Data Browser. In addition to internal integration projects, the I&M Information Manager serves as a member of the Natural Resource Data and Information Team (NRDIT). NRDIT routinely meets, discusses, and plans for interfacing and integrating the disparate group of natural-resource databases and information systems. NRDIT adopted an information management system called *Synthesis* as a standard interface for accessing resource data. I&M databases and information systems will work as integral components of *Synthesis*. I&M staff also communicate and coordinate data development, acquisition, and service with their counterparts in the NPS and with other agencies.

I&M Workshops and Training

The I&M Program sponsors and funds an annual training course that covers the fundamentals of planning and designing ecological monitoring, natural-resource inventories, and data management. Workshops are also funded to support development and implementation of ecological monitoring, natural-resource inventories, and information management. In FY 2000, the program is funding development of a data management workshop that focuses on hands-on, computer-based training of resource managers with databases and software tools developed by a variety of natural-resource programs. This workshop will include training with the *Synthesis* information management system, the ArcView GIS Data Browser, the NPS Species database, the Dataset Catalog database, the bibliographic systems, spatial metadata development, resource collecting permits and research reports, the NatureNet World Wide Web site and publications, and other appropriate materials. Much of the training will focus on data and resources acquired from the natural-resource inventories of the I&M Program. When developed and approved, the new data management workshop will be offered to NPS resource managers on a periodic basis.

Archiving of I&M Data

After several years of funding and initiating many servicewide inventories, the I&M Program is experiencing a significant and rising flow of data that must be managed and archived to protect the products and the investment in the program. I&M staff have been implementing a plan to provide near- and long-term management and archiving of inventory and monitoring data to best meet the needs of the National Park Service. The plan includes data acquisition, handling, conversion, and storage in the central office of the I&M Program and the Natural Resource Information Division in Fort Collins, Colorado, and distribution to other NPS units. Archiving and data formats are coordinated with other NPS and Department of the Interior programs. Data are archived on CD-ROM and stored in-house in the central office. Copies of the data are also supplied to the Technical Information Center in Denver, Colorado, NPS field technical support centers, and relevant NPS units. This combination of offsite and multiple-site archiving ensures the integrity of I&M data products. Acquisition of new equipment has facilitated processing of spatial data and GIS applications, recording digital inventory data on CD-ROM; scanning and digitizing maps, images, and aerial photographs; serving and maintaining service-wide databases that are critical to the I&M Program; and timely providing of data and archived products to parks and other cooperators. With the archiving facility substantially in place and functional, the increased database, GIS, and graphical capabilities

allow greater utility and synthesis of I&M data for more efficient resource and program management. Most of the work is being done with the assistance of research associates and student employees from the Colorado State University under supervision of the I&M Information Manager. During FY 2000, the I&M Program is supporting several Internet-based services including one Lotus Notes, two Oracle, one GIS, and two NRID World Wide Web servers. The program also supports several GIS workstations with ARC/INFO and ArcView software.

The I&M Training Course

The conservation of critical resources in parks requires comprehensive, interdisciplinary inventory and monitoring at the ecosystem level. The principles of that approach are described in *NPS-75 Natural Resource Inventory and Monitoring Guideline*, and training in appropriate designs and implementation of inventory and monitoring is provided in the *Natural Resource Inventory and Monitoring* course.

The course presents a systematic and holistic approach to inventory and monitoring and is designed to (1) describe alternative approaches, strategies, and methods for inventory and monitoring at the park level; (2) identify major ecosystem components for inventory and long-term monitoring, and (3) provide guidelines for data administration and reporting. It was designed primarily to meet the needs of personnel who are responsible for developing or coordinating the design of I&M programs in their parks and for supervising the implementation of these programs. Thus, a major focus of the course is on instructions that enable the participants to develop and implement inventory and monitoring that provides park-specific information for planning, management, and decision-making.

Specific features of the course are:

- the introduction of the concepts of ecology as applied to an integrated I&M program

- the presentation of a systematic approach for developing an integrated, holistic I&M program

- an explanation of the major steps in the I&M process outlined in NPS-75 and the development of a strategy for designing an integrated I&M program that meets specific park needs

- a discussion of the experimental design, statistical analyses, quality control, and assurance needs of an I&M program

- discussion of the role and methods of information management in an I&M program

- a presentation of a diversity of I&M case studies from parks.

In 1999, the course was held during 30 Aug–3 Sep 1999 in Gatlinburg, Tennessee. It included presentations by administrators, managers, and scientists from various governmental agencies, private organizations, and academe. Tentatively, *Natural Resource Inventory and Monitoring* will again be offered for 25-30 participants during August 2000 in Ventura, California

As the nation's principal conservation agency, the Department of the Interior has the responsibility for most nationally owned public lands and natural and cultural resources. This includes fostering wise use of land and water resources, protecting fish and wildlife, preserving the environmental and cultural values of national parks and historical places, and providing for enjoyment of life through outdoor recreation. The department assesses energy and mineral resources and works to ensure that their development is in the best interests of all people. The department also promotes the goals of the *Take Pride in America* campaign by encouraging stewardship and citizen responsibility for the public lands and promoting citizen participation in their care. The department also has a major responsibility for American Indian reservation communities and for people who live in island territories under U.S. administration.

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